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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

June, 1947

Photo by H. R. Tour

Upper drums of a large boiler go in place

Coal Looks Ahead ▶

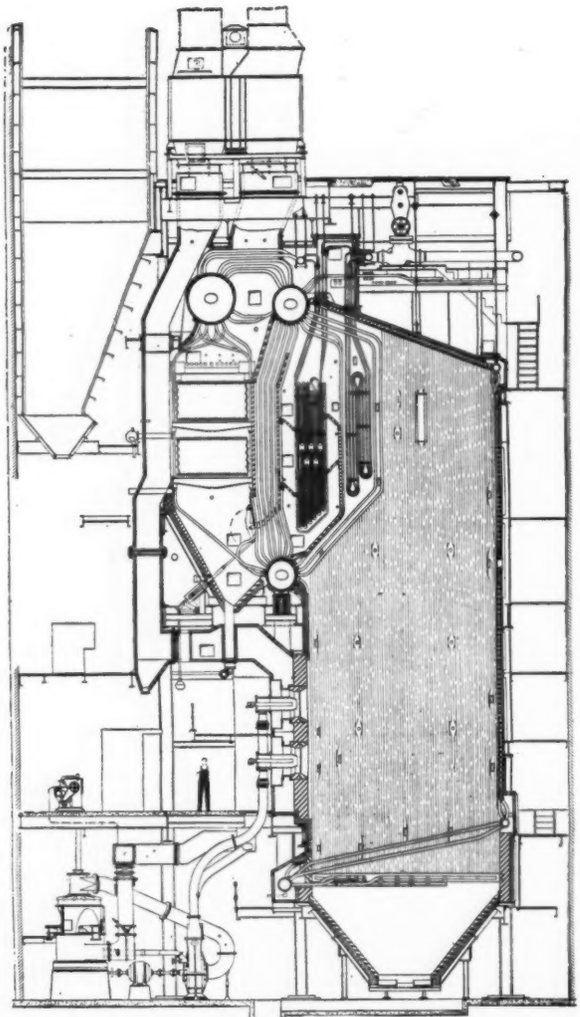
Notes on Compressors and Blowers ▶

Differences in Burning Characteristics of Similar Coals ▶

Recent C-E Steam Generating Units for Utilities

MANCHESTER STREET STATION

THE NARRAGANSETT ELECTRIC COMPANY



The C-E Unit, illustrated here, is nearing completion in the Manchester Street Station of The Narragansett Electric Company at Providence, Rhode Island.

It is designed to produce 450,000 lb of steam per hr at a pressure of 1225 psi at superheater outlet and at a temperature of 950 F.

The unit is a 3-drum type boiler with fin tube economizer in the last pass. The superheater is of the 2-stage type with gas flow controlled by a bypass damper. The furnace is completely water cooled using both finned tube and closely spaced plain tube construction. Pulverized coal firing is employed using C-E Raymond Bowl Mills and C-E Horizontal Burners. Burners are arranged to use oil as an alternate fuel. Regenerative air heaters follow the unit.

Another C-E Unit of about this capacity has been giving a good account of itself in this station since 1940, and a duplicate of the unit here described is now on order for future extension to the station.

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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME EIGHTEEN NUMBER TWELVE

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Published monthly by COMBUSTION PUBLISHING COMPANY, INC., 200 Madison Ave., New York 16
A SUBSIDIARY OF COMBUSTION ENGINEERING COMPANY, INC.

Frederic A. Schaff, President; Charles McDonough, Vice-President; H. H. Berry, Secretary and Treasurer.

COMBUSTION is sent gratis to engineers in charge of steam plants from 500 rated boiler horsepower up and to consulting and designing engineers in this field. To others the subscription rate, including postage, is $2 in the United States, $2.50 in Canada and Great Britain and $3 in other countries. Single copies: 25 cents.
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Issued the middle of the month of publication.

Publication office, 200 Madison Ave., New York CCA Member of the Controlled Circulation Audit, Inc.

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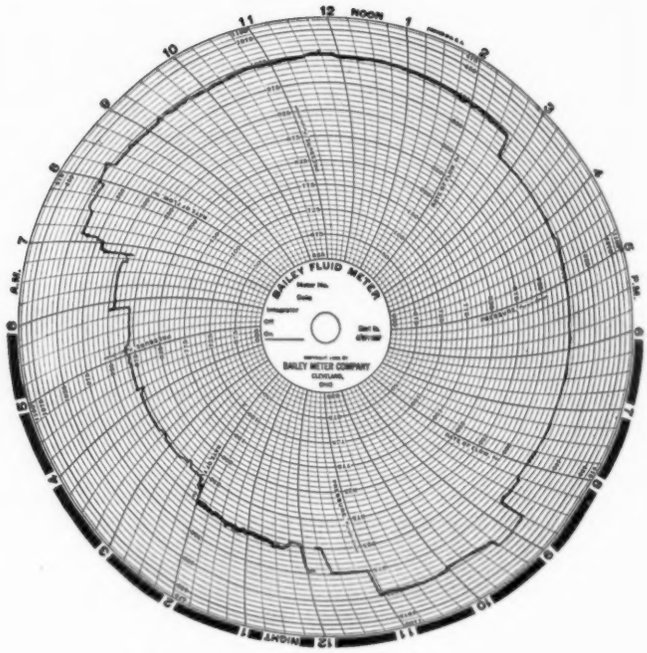
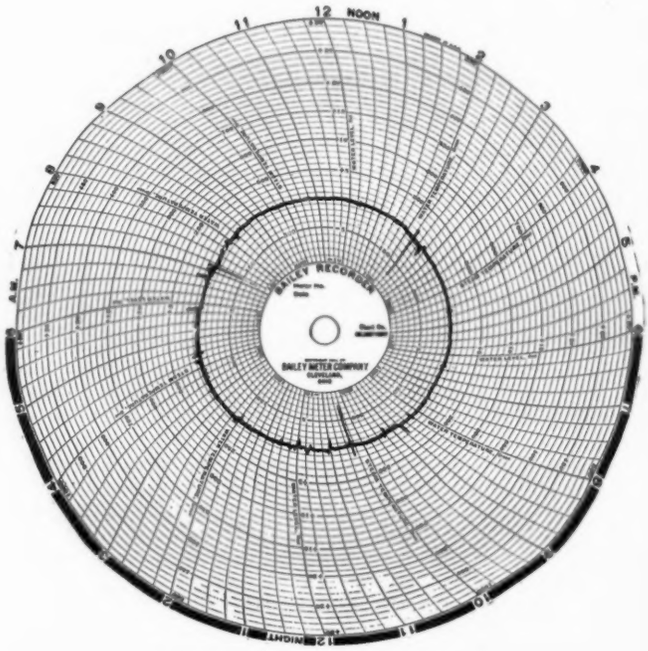


Load range is 160,000 pounds per hour



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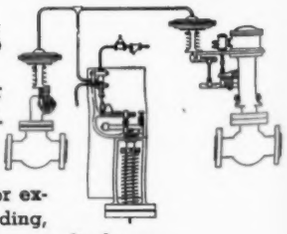

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EDITORIAL

World Power Conference Meeting Revived

Eleven years have elapsed since the Third World Power Conference was held in the United States in September 1936. As many will recall the general program, largely dictated from Washington, was confined to economic subjects such as energy sources, conservation, public power development, regulation of utilities, planned utilization of water resources, rural electrification, etc. Technical subjects, including those pertaining to steam plants, were dealt with in Round-Table Meetings before and after the main Conference and were held in conjunction with plant study tours. Unfortunately, these discussions were somewhat curtailed by the fact that the German delegates, then under Nazi domination, were not free to participate fully.

The World Power Conference organization has again become active and has scheduled a sectional meeting in the form of an international Fuel Economy Conference to be held at The Hague in September. It is gratifying to see that the tentative program accords consideration to the technical as well as the economic aspects of this important and timely subject. While present travel problems may limit the attendance, especially from this side of the Atlantic, the success of the meeting seems assured and engineers will then look forward to the next General Conference.

Oil Users Face Curtailment

The present price of residual fuel oil in the East, together with inability of some suppliers to meet current demands and others to assure continuous supply, is causing some users to revert to coal. The recent twenty cents per barrel rise in price of this oil brings the total increase since last summer up to fifty cents per barrel, and thus in many localities favors bituminous coal on a price basis. To what extent this situation may be changed as a result of present negotiations between the coal operators and Mr. Lewis, or whether there is likely to be another stoppage in coal supply after July first, when the Government relinquishes control of the mines, is anybody's guess. This is causing some industrials and commercial users to hesitate on immediately switching to coal.

The critical situation in the supply of residual oil is attributed to the unprecedented high demand that followed the lifting of war restrictions, augmented by shortage of natural gas in certain areas, and curtailment of production of these heavy oils to meet demands for maximum yields of gasoline, diesel and house-heating oils. Relief cannot be expected until refining capacity and transportation facilities are expanded and these, in turn, are being delayed by the materials situation. Meanwhile, a swing toward stokers may be expected.

The Government viewpoint on the current oil situation was recently expressed by Max Ball, Director of the Oil and Gas Division, Department of the Interior, who said:

"We are now running very close to the maximum efficient rate of production. Transportation is just up to capacity and refining is up to capacity. We are trying to do a job considerably bigger than we did before the war or during the war, with only the tools we had at the end of the war.

"We are trying to stretch our facilities, and if everything works we will just get by. The amount of cold weather, the degree of slackening of industrial activity, and the number of strikes in the petroleum industry, will determine whether we will have cold homes and idle plants this winter."

Looking back over the years, increases in fuel oil prices have usually followed a competitive pattern with those of coal, but it would appear that the present increases are also intended to some extent to function as a check on excessive demand.

It is not the large boiler units that are seriously affected, as most of these in the East operate on pulverized coal, or are provided with combination burners, permitting use of pulverized coal or oil. Instead, it is principally the smaller industrial plants and commercial users who are faced with the uncertainty. It is most unfortunate that the whole fuel situation cannot become more stabilized.

Pulverized Coal in Britain

The successful application of pulverized coal to steam boilers is approximately twenty-five years old, most of the pioneer work having been carried on in the United States where its development went hand-in-hand with that of large steam-generating units. Britain was slower to adopt, generally, this type of firing and for a long time continued to cling to stokers for most of its larger units. However, the importance which British engineers now attach to this subject is indicated by the recent Conference on Pulverized Fuel held at Harrogate under the auspices of the Institute of Fuel. This occupied four days, from June 3 to 6, and comprised fifty-nine technical papers. While a few of these were contributed by other than British authors, by far the greater number dealt with British practice and development, thus reflecting the ever-widening application of pulverized fuel in that country for both steam generation and industrial furnaces.

COAL LOOKS AHEAD

By GEORGE H. LOVE

President, Pittsburgh Consolidation Coal Co.

In these excerpts from an address before The Executives Club of Chicago on May 9, the author reviews the rôle of coal in this country's economic supremacy and compares the output per miner with that in England where the industry is socialized. The present two fundamental weaknesses of the coal industry he regards as labor relations, aggravated by Government interference, and the very large number of producers, representing some 12,000 mines. Safety measures, mechanization and research are also discussed.

IN THIS industrial age, no country can be greater than its sources of energy. Our highly productive economy has been built up by increasing the primary use of energy, which, in turn, has increased productivity and created a society known throughout the world as the "Land of Plenty."

During the last century output per man-hour has increased almost five times while the work week has been reduced by approximately one-third. This has been accomplished by increasing the use of mineral power some 343 times during that 100 years. This mineral power, whether in the form of coal, petroleum products or natural gas, has been supplied in this country at a lower cost and in greater abundance than energy is supplied in any other major nation. But, since almost all the reserves of this energy are in coal, what happens to coal is a forerunner of what will happen to the country.

Labor Relations a Weakness

Let us take a look at this coal industry, first reviewing its primary weaknesses of which there are two. One of these is its national labor relations, particularly during the last six years. Think of the numerous Government seizures, the last one still continuing in effect after almost a year. Think of the strikes during the war; those since the war; and of the recurrent threats of strikes, which are almost as damaging as the actual strikes. At whose door shall we lay the blame for this condition of affairs?

Many would place the blame on the leadership of the union; others who would assign the responsibility to the Government or to the coal operators. Without attempting to place the blame, it seems an inescapable conclusion that a large part of this trouble at least stems from the consequences of Government policy and actions. Perhaps if I were a labor leader and knew, as on retrospect Mr. Lewis apparently knew, that I could extract more from the Government than I could get by bargaining with the operators, I would have followed the course taken by Mr. Lewis.

The Government first stepped in to make a wage contract for the coal industry in 1943 under the guidance of Mr. Ickes. The maneuver was repeated in 1946 under the direction of Mr. Krug. These two agreements so generously entered into by the Government are now costing the coal industry and the consumers of coal some $400,000,000 a year, or in excess of 75 cents a ton. The total of $400,000,000 is made up of the following:

Travel time		$120,000,000
Krug-Lewis bonus		185,000,000
Welfare fund		29,000,000
Tools, lamp service, blacksmithing		9,000,000
Lunch period		37,000,000
Vacation increases:	Ickes-Lewis agreement	7,000,000
	Krug-Lewis agreement	13,000,000

There is reason to believe that the Government recognizes its errors of the past. To the extent that this proves to be the case, we may now regain the right to bargain on what is to become of the dollars originally provided by the owners and sustained by our customers. This is certainly preferable to having a benevolent government give these dollars away.

What the great bulk of this industry wants and needs today is peace. Not just month-to-month peace, nor even year-to-year peace, but continuing peace so that those dependent on coal may see increasing stability in the industry; that is, reliability of production, quality and price.

Twenty or thirty years ago, strikes in this industry were not so serious: first, because the strikes were seldom industry-wide; and second, coal not mined one month could be mined the following month, and nobody was inconvenienced too much. This is not true today, when the nation's productive machine is desperately in need of all raw materials.

What lies immediately ahead for the coal industry in the matter of labor relations may be determined by the success of that segment of the industry which is now willing and has embarked on an effort to make a sound agreement with Mr. Lewis without the interference of the Government. I feel that this large segment of the industry, comprising about 70 per cent of the national bituminous production, will conduct itself in these negotiations so as to warrant the confidence of the public and, should it be necessary, the support of Congress.

Personally, I hope that both Mr. Lewis and we of the industry, having seen enough of Government in this business, are determined to conclude an agreement and move on with the tremendous job which the nation has a right to expect from coal.

Too Many Producing Companies

The other fundamental weakness of the coal industry revolves around the very makeup of the industry itself. Picture an industry with a sales volume less than half that of the steel industry and yet with nearly a hundred times

as many producers. The bituminous coal industry has some 12,000 mines scattered over some 23 states, and these mines vary in size from those employing two or three men to those with pay rolls of a thousand or more. Six thousand different companies are normally spinning around in a whirlwind of price competition with their neighbors, with other districts, and with other fuels.

In all but war and boom periods, capacity exceeds consumption by a large margin in the coal business. So most of the time there are 6000 companies trying to manage a business with a tremendous over-capacity in which it sometimes pays to operate at a loss rather than to close down. It is hard for a layman to understand this paradox, unless he places himself in the position of the owner of a single mine. Assume that demand falls off, and he is faced with the choice of closing down completely, with the loss of the entire investment; of spending large sums to hold the roof in place, to keep the water pumped out, and otherwise maintain the mine in operating condition; or of continuing to mine some coal and sell it at a loss. Generally, the last course would be followed while hoping for better times to come.

From 1925 to 1940, the bituminous coal industry with its scattered, fragmentary system lost $350,000,000. And yet we know that to make progress for itself and for the country, an industry must make a profit. When we compare coal with other large industries which have accomplished so much for the country, the problems of the coal industry stand out clearly.

Concentration in Other Fields

In the oil industry, the chief competitor of coal today, one company has assets equal to those of the whole coal industry and earns more than the total coal industry, even in times of peak demand. In rubber, four companies produce 70 per cent of the total volume. One company is reported to supply 60 per cent of the nation's electrical generating capacity. Three companies in the automobile industry supply over 75 per cent of the automobiles. There is a similar situation in aluminum, steel, chemicals. In coal, however, it would take the top four commercial companies combined to equal even 10 per cent of the productive capacity. The coal industry's scattered, heterogeneous condition, from the financial, the management and the geographical standpoints, is undoubtedly the most inherent and fundamental problem we face.

There is, however, a present trend toward some concentration which is the result of more and more machinery being placed in the mines.

Our own company mines coal in four states, operating some 40 mines, many of which were in the hands of small companies some years ago. Until recently almost anyone could enter the coal business by leasing a small acreage of coal, hiring a few men and finding a few mules. Today, allowing a reasonable price for sufficient coal acreage to permit operations for a minimum of 20 years, it costs some $8,000,000 to develop and equip a modern mine with proper preparation facilities large enough to produce and market 1,500,000 tons per year. These larger mines are essential because not only will they mine the coal cheaper, but they will prepare it for market in predictable and more acceptable quality, as well as give the consumer a greater assurance of stable supply and price.

Miners' Wages

The coal industry has been dramatized as the center of low wages and destitution. Here is a case where the public understanding has lagged far behind the facts.

What are the facts on wages?

Just last week a Washington, D. C., newspaper published figures on wages issued by the Bureau of Labor Statistics. These showed that the highest weekly earnings of any industry in January of this year were in the coal industry, where the men averaged $69.58 per week. It was interesting to note that the nearest approach to this average in the coal industry was the weekly average of $60.00 in rubber. Steel was $50.00 and the railroads, $58.70.

It might be added that the average hours worked in coal during 1946 were 46.7, although work was available for most of the men for 54 hours. Had they worked this available time, coal miners would have swelled their average weekly earnings to over $80. There are many miners who earn well in excess of $400 per month. In 1945, the latest year for which comparable figures are available, the English miner earned about $23 per week as compared with the $55 average weekly paycheck received by the miner in this country.

Safety Measures

The recent Centralia disaster has been used to indict the coal industry for inhuman disregard of the safety of its workers. There is no industry in the world to which the word "safety" means more in the way of planning and effort and training on the part of management than it does to the coal industry. Still we can never lose sight of the fact that coal mining is hazardous. There are constant and diverse dangers from falling roofs, from the maze of underground railroads, from the movement of large equipment in small areas, and from the presence of gas and dust. However, in spite of these hazards and human factors beyond the effective control of management, the bituminous coal industry has made steady progress in this most important activity. Let me quote from Dr. Sayers, Director of the Bureau of Mines:

"In 1942, the coal mining industry lost 1471 workers through fatal accidents, and in spite of the continued withdrawal of younger workers from the mines by the armed forces and further deterioration of irreplaceable mining equipment during the war years, the industry reduced fatalities in 1943 and again in 1944, 1945 and 1946."

Despite its recent claims and demonstration, I only wish the union was as safety-conscious as their dramatics would indicate. Actually, there is continued fighting and striking as a result of our efforts to get men to obey safety regulations. For example, if a man is penalized for repeated infractions of safety rules, the union fights and often calls a strike to force abatement of his penalty. Hard, protective hats are required by many State laws, and we have had strikes where men refused to abide by these laws and wear the hats designed for their protection. As another example, we have a mine in Ohio which the Federal inspector would not permit us to reopen following the recent memorial strike until we posted bulletins announcing a no-smoking regulation. The very next day the 700 men employed in this mine refused to resume operations unless the regulation were withdrawn. The

operators are doing everything they know to do to make mines safe. The final step rests with the union. Can we get this cooperation from the union to make mines safe? That is the question.

Productivity Compared with Other Countries

Finally, let me point to the third fashionable myth about coal. It frequently comes from men who haven't seen a coal mine in 20 years, if at all, to claim that coal is the industrial laggard in technological development. I will make only a brief defense here, for one statement should suffice. Coal mining in this country is much further advanced over that in other countries than is any other major industry in comparison with its foreign competition. In other words, our mining here has made greater advances over coal operations in England, Germany or Poland than, for example, have the steel industry or chemical industry surpassed the achievements of English or German steel or chemical plants.

We have had a constantly rising productivity which has more than doubled since 1900, and I believe this will continue even as we mine thinner and longer-haul coal. We produce over 5 tons per man-day in this country as compared to England's 1.1 tons. England produced 333 tons per man employed in the year 1883 and has never exceeded that record. Our own underground workers in our company produced over 1500 tons per man in 1946 despite over two months of strike shutdowns.

Over 50 per cent of our coal in this country is now mechanically loaded rather than shoveled, whereas only 1 per cent is so loaded in England, which was completely dependent on coal for its economic life.

Fuel Reserves

If we compute the fuel energy reserves of the United States in terms of bituminous coal, we find the equivalent of slightly less than 5 billion tons of petroleum and slightly more than 5 billion tons of natural gas; whereas coal reserves reach a figure of nearly 3 trillion tons of bituminous coal. At the present time this country requires primary energy to the extent of about 1.26 billion tons, approximately half of which is furnished by coal. Petroleum furnishes one-third, natural gas one-eighth and hydroelectric power one-twenty-fifth. Our total energy needs a decade from now have been forecast as 1.5 billion tons coal equivalent. At this rate of growth, if petroleum alone were called upon to satisfy our total energy requirements, we would exhaust the reserves in less than four years; and natural gas, if it were called upon to assume the full burden, would only last a fraction of a year longer.

Putting this another way, if either petroleum or natural gas had been called upon to carry this country through the war unaided by other fuel sources, it would now be exhausted. So whether we like it or not, we must look to coal to satisfy our energy needs.

I acknowledge that in the short-term view there may be some encroachments on present coal markets by oil and natural gas. This is particularly so when people want luxuries and more conveniences and are willing to pay for them. Among the railroads, there will be some switching to diesels. But let me add that the expansion of our needs for energy, particularly electrical power, and in the growing uses for chemicals where coal will carry the base load, will more than offset any encroachments.

The inevitable increase in the cost of finding and developing new fields of petroleum and gas is another factor working in coal's favor. But we do not intend to coast on these natural trends. Where would the oil industry be today if kerosene were still its chief product? We in the coal industry must wrap up the energy that is in coal into a different package so that this energy can be used to the best possible advantage.

Current Research

We are deep in research for better, safer and cheaper mining. We are participating with a few other coal companies and railroads in paying for the development of the gas turbine locomotive which, I believe, will eventually beat the diesel. We are also spending money with other companies to find better means of burning coal as a solid. But our particular path in research leads directly to coal gasification, and from there to the making of high-heat value gas and high octane gasoline.

This project in coal gasification, on which we soon will begin construction of a $300,000 pilot plant near Pittsburgh, Pa., is being conducted in collaboration with Standard Oil Development Company.

After all, coal is made up primarily of hydrogen and carbon atoms. The same is true of natural gas and petroleum. Alcohols, which are turning out to be the basis for new chemical developments in plastics and any number of other things, are again made up of hydrogen and carbon with oxygen added. The pilot plant will enable us to prove that the job of rearranging atoms to form gas and gasoline can be done on a commercial basis as it has already been done in the laboratory. We are contributing with other oil companies to the building of a pilot plant using a somewhat different method by Hydrocarbon, Inc., in New Jersey.

The actual time when construction of a commercial-size plant will be started in Western Pennsylvania depends on the economics involved, but the trend toward higher development and recovery costs of natural gas and petroleum and the possibility of finding better methods by pilot plant operation lead us to believe that the time when we will start engineering such a plant will not be long delayed. Such a plant near Pittsburgh might cost as much as $120,000,000, but it could produce gas in quantity equal to the carrying capacity of both the Big and Little Inch Pipe Lines, and by the time these lines are fully equipped the total investment will be close to $200,000,000. But think what it means to Western Pennsylvania, or to areas in Illinois where large coal reserves exist, when these coal refineries are in operation. The size refinery or plant we are considering will use 20,000 tons of coal a day. This would mean work for almost 6000 people and support to a community of 30,000 people. These figures are cited to show the real meaning of this coal gasification project in terms of employment and security as opposed to pipe lines built to carry a competing commodity across coal fields which would provide relatively nothing in employment.

Inasmuch as the process calls for complete gasification of the coal before that gas is turned into gasoline, or into high-heat value commercial gas, the relative output may be changed from more gasoline and less gas to less gasoline and more gas. Thus, it will be seen what a tre-

mendous advantage can be had in taking care of the winter peak load for gas and the summer peak load for gasoline with this flexible fuel.

Some may wonder what place atomic energy may take in our expanding industrial world. No one knows the answer to that, but I do not think it will interfere in the foreseeable future with coal in this country. A published report, by Dr. Thomas of Monsanto Chemical, points out that an atomic power plant might be built for $333 per kilowatt and, with 100 per cent load factor, produce a kilowatt hour for 8 mills. A modern steam utility using coal can be built for $120, or about one-third the capital cost of the atomic power plant, and produce a kilowatt-hour for 3 mills. No plant operates with 100 per cent load for its lifetime, and obviously the great difference in cost goes up much further as the load decreases. Atomic energy may come in, but places remote from coal regions would be the first sites.

Test Results at Anchorage

Some readers may recall an article in the August 1946 issue, by H. G. Meissner, in which the author related experiences during the early period of the war in flying to Alaska and, under very unusual circumstances, conducting acceptance tests on the boilers of a new power plant at Fort Richardson, which also served the town of Anchorage and an adjacent air field.

At the time of preparing this story, the report of test results on the equipment was buried in the files of the War Department and no one seemed able to locate it. Quite recently a copy of this report has come to light and has been made available by the Headquarters of Alaskan Service Base at Seattle, Wash. Therefore, to supplement the original story some figures from the test results are here given.

It will be recalled that the installation consisted essentially of three 120,000-lb per hr C-E single-drum sectional-header boilers, equipped with over-deck superheaters; two fired with C-E spreader stokers and the third oil fired, with the stoker covered over. The steam conditions at the superheater outlet were 210 psi and 500 F with 292-F feedwater. The grate surface of each coal-fired boiler was 25 ft wide by 13 ft long.

Alaska coal was burned on the test, averaging 10,680 Btu per lb. 35.5 per cent volatile, 9.9 per cent moisture and 14.5 per cent ash.

An efficiency test was conducted, in accordance with the A.S.M.E. Power Test Codes on boiler No. 2 and sustained capacity tests on the other coal-fired and oil-fired units. At an average load of 123,500 lb of steam per hour the overall efficiency of the unit was 77.9 per cent which figure exceeded the guarantee. Moisture content of the steam at no time exceeded $^1/_2$ of 1 per cent. No difficulty was experienced in maintaining full load of 120,000 lb per hr on the other units.

The test report issued by Bechtel-McCone-Parsons Corp., of Los Angeles, the engineers and constructors, also gives the results of the turbine tests, there being two 3750-kw 2300-volt 60-cycle Westinghouse turbine-generators—one condensing with automatic extraction at 50 psi and the other of like capacity but designed for non-condensing operation at 50 psi back pressure. Both take steam at 200 psi 500 F at the throttle and the condensing unit operates at 28-in. vacuum.

Testing the condensing unit with the extraction pressure control cut out, the following water rates were measured at different loads:

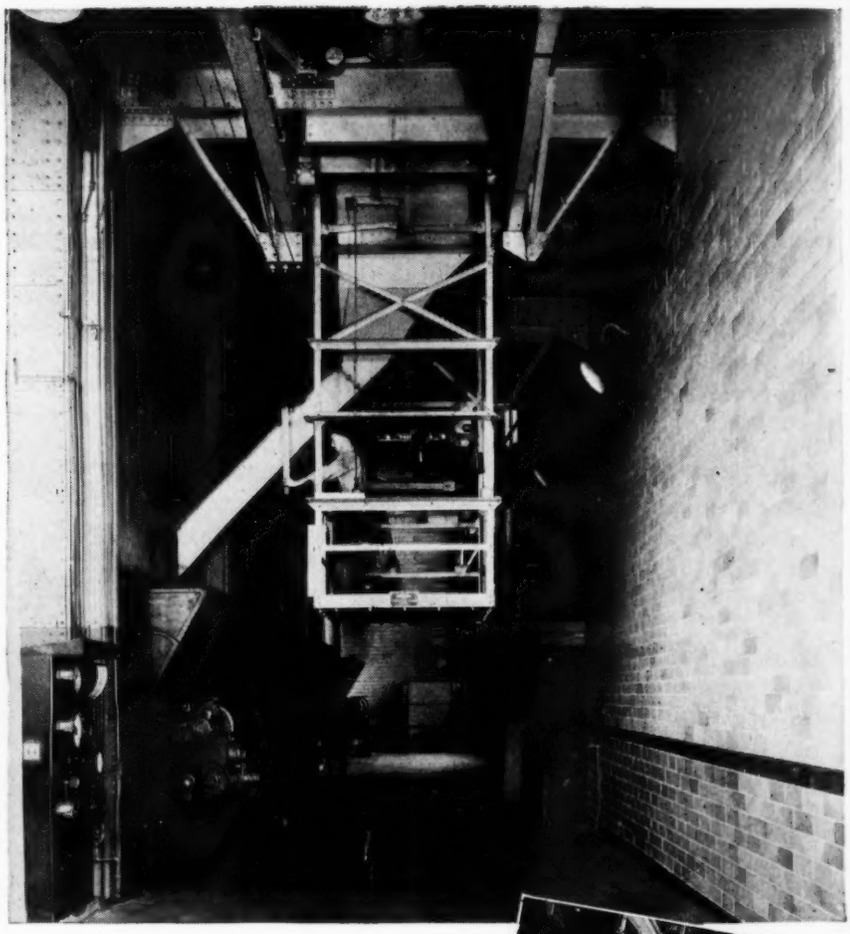
Kw output	Water rate, lb per hr
750	16.0
1500	13.5
2250	11.1
3000	12.4
3750	12.5

These points will be found to fall practically on a straight line and therefore conform to a typical Willans Line.

Tests on the noncondensing unit gave the following results:

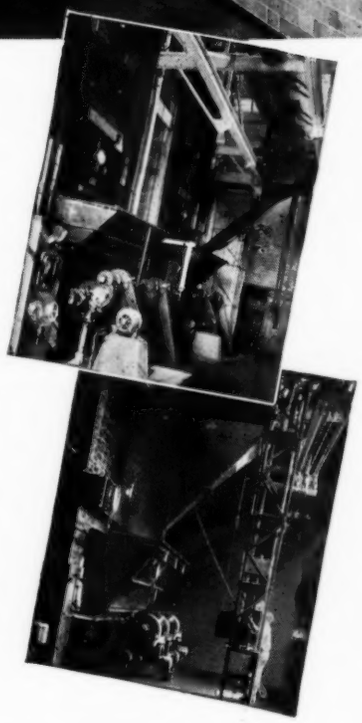
Kw output	Water rate, lb per hr
750	69.3
1500	50.7
2250	45.5
3000	43.0
3750	44.6

While these figures for the boilers and turbines are not comparable with later large units, nor with those of similar size operating under more favorable steam conditions, they nevertheless are representative of many smaller units now in service.



WEIGH LARRIES

from 1/2 ton capacity up



BARTLETT-SNOW Weigh Larries eliminate segregation. They produce an even dispersion of lumps and fines in the stoker hopper, resulting in ideal draft and burning conditions, —and cost less than fixed chutes each fitted with cut-off gates, scales, etc. when four or more stokers are being served from an overhead suspension bunker. Weigh Larries permit the use of a cylindrical coal bunker located at the end of the building, simplifying building construction, assuring ample light and ventilation, and easy access to the boilers for maintenance and repairs. Furnished in hand propelled and motor-driven, floor or cage operated types. Send for Bulletin No. 83. It gives full details.

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COAL HANDLING FOR CENTRAL STATIONS AND INDUSTRIAL BOILER PLANTS

Notes on Compressors and Blowers

The Compressed Air and Gas Institute, Cleveland, O., has completed a comprehensive "Compressed Air Handbook" which it expects to issue around September first. It deals with applications of compressed air and gas in various fields, includes a vast amount of engineering and economic data, outlines test procedures for compressors, blowers and exhausters, and contains practical information on the care and operation of such equipment.

The Institute has just made pre-publication proofs available to the technical press for such partial advance use as may seem desirable. Hence the following notes are taken at random from the text with the thought that they may be of interest to COMBUSTION readers.

STANDARD types of stationary reciprocating compressors include: (*a*) vertical and V-type single-acting units in sizes up to 100 hp single-stage, and two-stage, either air- or water-cooled; (*b*) vertical or V-type semi-radial and right-angle type double-acting machines, available in sizes of 60 hp and above, single- and multi-stage, and water cooled only; (*c*) single-frame horizontal or vertical double-acting compressors, available in sizes up to 125 hp, single- and multi-stage, and water-cooled only; (*d*) duplex, horizontal or vertical double-acting machines in sizes of 75 hp and over, single- and multi-stage and water-cooled only.

Choice between single- and two-stage compression depends upon many varying factors such as size of cylinders, speed, ratio of compression, discharge temperature limitation, cost of power, continuity of service, method of cooling, permanence of installation, etc. In general, the dividing line between single- and two-stage air compression for double-acting compressors may be drawn as follows, assuming sea level and atmospheric intake conditions.

For pressures below 60 lb, single-stage; for pressures above 100 lb, two-stage; and for the range between these pressures, single-stage for capacities below 300 cfm and two-stage for larger sizes.

Cost of power is an important factor in selecting the type of compressor. Because of the relatively long life of compressor equipment, higher efficiency with consequent lower power cost often justifies a higher initial investment.

Steam drive is available for most double-acting compressors, with the engine usually an integral part of the machine; and electric drive for those of any capacity. For driving belted and high-speed direct-coupled compressors, of 125 hp and below, the squirrel-cage induction motor is generally used, although a synchronous motor is occasionally employed because of its capacity for power factor correction.

Direct-connected synchronous motor drive for multi-cylinder, double-acting compressors is used almost universally in sizes of 100 hp and larger, and is popular even in sizes as small as 60 hp.

Application of an electric motor to a compressor, especially when of the synchronous type, should be studied carefully as questions of starting torque, starting current and suitable flywheel effect require close analysis. However, purchasing the motor from the compressor manufacturer avoids division of responsibility for this engineering.

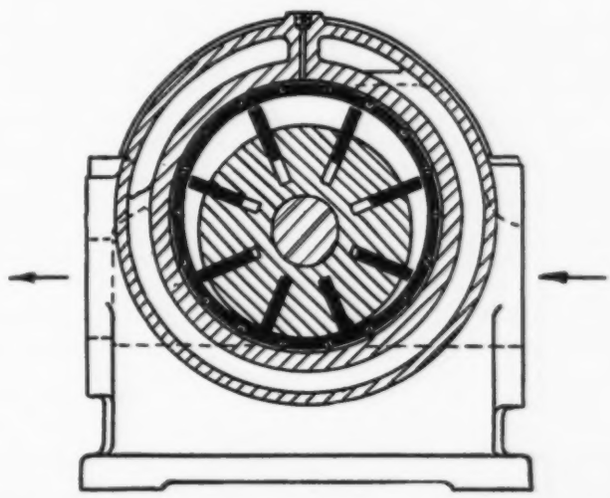
Internal combustion engines are frequently used for driving stationary compressors where the cost of suitable fuel is favorable or other forms of power are not available.

Steam-driven compressors operate at varying speeds and are usually provided with combination speed and pressure governors either of the throttling or the automatic cut-off type.

The capacity of a positive displacement-type compressor, working under a given ratio of compression is not affected by barometric pressure or temperature at the compressor intake.

Motor-driven and other constant-speed compressors are usually provided with one of three general types of capacity control. These are:

1. Constant-speed control which decreases the compressor capacity automatically in one or more steps while the machine continues to operate at normal speed.
2. Automatic start-and-stop control, in which an automatic starter and pressure switch start and stop the motor within definite pressure limits. This control is recommended only when there is no demand for air for



Rotary sliding-vane type compressor or vacuum pump with floating rings

fairly long periods; and it should not be used where very close regulation of the pressure is necessary.

3. Dual control is a combination of 1 and 2. It permits continuous operation when the demand is fairly continuous and automatic start-and-stop operation during periods when there is little demand.

When judging the relative performance of compressors, purchasers are frequently confused by such incidental factors as mechanical efficiency, compression efficiency, etc. Only the actual capacity of the compressor and the energy or power it requires per unit of air actually delivered should be considered, as they are the real criteria of a compressor's efficiency. However, attention is invited to the different economy bases used for steam- and for motor-driven compressors. Steam consumption of steam-driven compressors is given per hundred cubic feet of free air actually compressed, whereas with motor-driven machines, it has been the custom to divide the horsepower of the compressor by the actual capacity per minute, and express the performance in horsepower per hundred cubic feet per minute *actual* capacity.

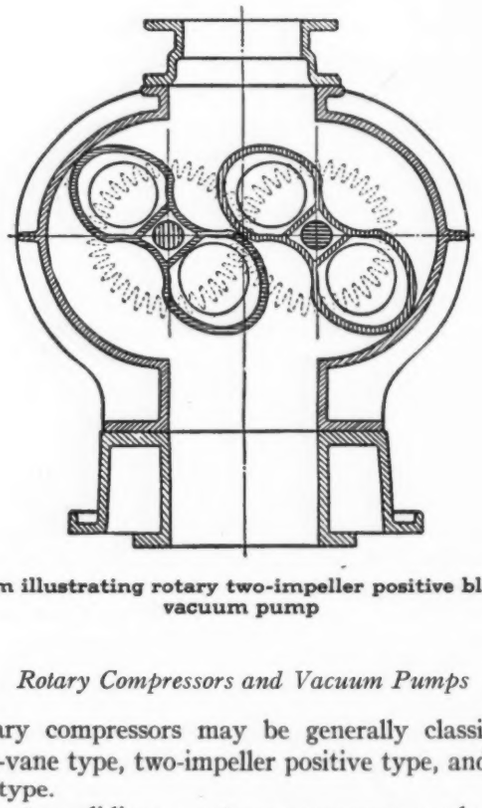


Diagram illustrating rotary two-impeller positive blower or vacuum pump

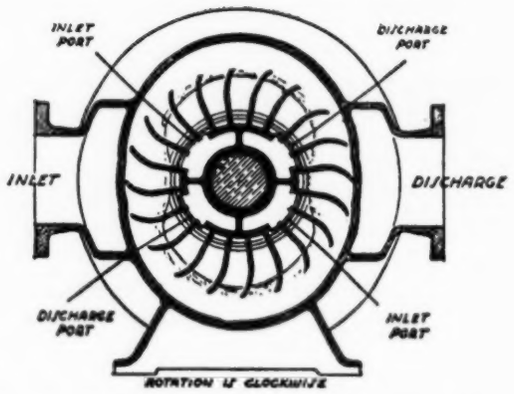
Rotary Compressors and Vacuum Pumps

Rotary compressors may be generally classified as sliding-vane type, two-impeller positive type, and liquid piston type.

The rotary sliding-vane type compressors and vacuum pumps are available in two principal designs, namely, those employing "floating rings" which do not allow the blades to bear on the cylinder wall, and these without floating rings which permit the blade edges to contact the cylinder wall throughout each complete revolution. Such compressors are available in standard sizes up to 5300 cfm and pressures up to 125 psig; also as booster units in higher pressure ranges. Speeds range from 3600 rpm in the small sizes to 450 rpm in the large sizes.

Generally, single-stage machines are offered for pressures up to 500 psig and vacuum to 28–29 in., referred to 30 in. mercury barometer; and two-stage machines for pressures up to 125 psi and 29.9 in. Hg.

Rotary two-impeller positive-type blowers and vacuum pumps are built for capacities from 5 cfm to about 50,000



Showing operating principle of rotary liquid-piston type compressor or vacuum pump

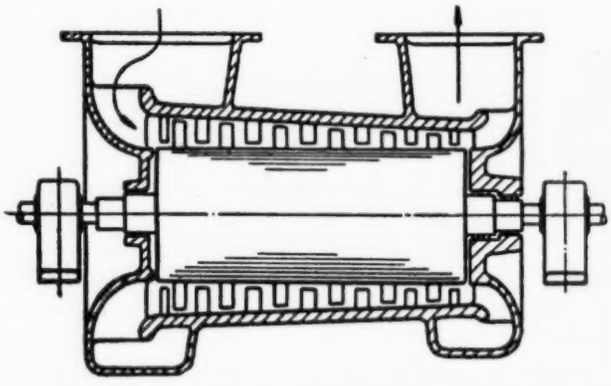
cfm and for pressures up to 10 psig in single-stage arrangement for medium capacity requirements and for pressures up to 15 psig where large volumes are handled. In the two-stage arrangement, this type of compressor is built for pressures up to 30 psig.

Rotary liquid-piston type compressors and vacuum pumps employ a liquid, either water or other low-viscosity fluid, as the compressant. A single moving element (a round rotor with shrouded blades forming a series of buckets) revolves freely and without wearing metallic contact, in an elliptical casing containing the liquid. The liquid is carried around by the rotor, but actually follows the contour of the casing. The latter being elliptical, the liquid is caused to recede from the rotor buckets at the wide point (major axis) of the ellipse, thus permitting the buckets in the rotor to fill with air or gas from the stationary inlet ports. As the liquid reaches the narrow point of the ellipse (minor axis) it surges back into the rotor buckets, compressing the gas and ejecting it through the stationary discharge ports.

This type of compressor develops up to 75 psig in a single stage and has a capacity range from a few cubic feet per minute to about 5000 cfm.

Centrifugal and Axial Blowers, Compressors and Exhausters

In these machines air or gas is compressed by the dynamic action of rotating vanes or impellers which impart velocity and pressure to the flowing medium. Flow will be radial or axial as the name implies.



Multi-stage, single-flow uncooled axial blower or compressor

The term blowers is usually applied where the final pressure does not exceed 40 psig, and they are seldom water cooled. On the other hand, where the final pressure exceeds 40 psig the term compressor is employed. This is usually water-cooled.

Exhausters are blowers or compressors in which the inlet pressure is less than atmospheric and the discharge pressure is equal to or greater than atmospheric.

A single-stage centrifugal blower has only one impeller and may be of either the single- or double-inlet type, uncooled. Capacities range from 500 to 100,000 cfm with pressures from about 1 psig for small machines to 6.5 psig, or more, for larger capacities. Multi-stage blowers or compressors have two or more impellers in series; they may be of the single- or double-flow type; and capacities range from 500 to 150,000 cfm, or more, with pressures from 1 to 150 psig. Axial compressors are available for even greater capacities.

Whereas centrifugal machines deliver practically constant pressure over a considerable range of capacities, axial machines are characterized by substantially constant capacity delivery at variable pressures.

Since the casing size and the horsepower required to drive a centrifugal or axial machine are a direct function of inlet capacity, care must be exercised in specifying the capacity. "Standard" capacity is frequently used in specifications, but since there are several standards in common usage, it is necessary to include sufficient information to properly correct the "standard" capacity to inlet capacity. Air is frequently specified at conditions of 14.7 psia, 60 F and saturated with water vapor. However, "Standard Air," as adopted by the A.S.M.E., is defined as air at a temperature of 68 F, a pressure of 14.7 psia and a relative humidity of 36 per cent (0.075 density); although in the gas industry 60 F is usually employed and 32 F is sometimes used in the chemical industry. It is also important to establish accurately the discharge conditions and the gas specific gravity, if gas is the medium to be handled, in order to be able to calculate the head that must be developed by the machine and to determine the number of stages required.

Centrifugal and axial machines are usually driven by electric motors or steam turbines, either direct-connected or geared. With constant-speed motor-driven machines, it is frequently desirable to employ a throttle valve for varying capacity and/or discharge pressure.

EQUIPMENT SALES

as reported by equipment manufacturers to the Department of Commerce, Bureau of the Census

Boiler Sales

Stationary Power Boilers

	1947 Water Tube		1946 Water Tube		1947 Fire Tube		1946 Fire Tube	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	161	1,072,366	173	1,109,924	106	106,788	113	154,064
Feb.	149	954,013	197	1,262,520	90	99,267	126	171,100
Mar.	168	863,292	171	1,357,650	80	109,984	123	180,552
Jan.–Mar. incl.	478	2,889,671	541	3,730,094	276	316,039	362	505,716

* Includes water wall heating surface.

Total steam generating capacity of water tube boilers during the period Jan.–Mar. (incl.), 1947, 34,259,000 lb per hr; in 1946, 28,908,000 lb per hr.

Marine Boiler Sales

	1947 Water Tube		1946 Water Tube		1947 Scotch		1946 Scotch	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	2	7,724	2	11,276	—	—	1	590
Feb.	2	1,423	—	—	—	—	—	—
Mar.	5	22,232	—	—	—	—	4	1,706
Jan.–Mar. incl.	9	31,379	2	11,276	—	—	5	2,296

* Includes water wall heating surface.

Total steam generating capacity of water tube boilers sold in this period Jan.–Mar. (incl.), 1947, 642,000 lb per hr; in 1946, 60,000 lb per hr.

†Mechanical Stoker Sales

	1947 Water Tube		1946 Water Tube		1947 Fire Tube		1946 Fire Tube	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Jan.	67	32,532	61	35,757	148	22,320	184	23,323
Feb.	55	32,759	71	40,880	122	19,946	175	27,708
Mar.	55	26,956	94	45,646	225	29,705	181	28,071
Jan.–Mar. incl.	177	92,247	226	122,283	495	71,971	540	79,102

† Capacity over 300 lb of coal per hour.

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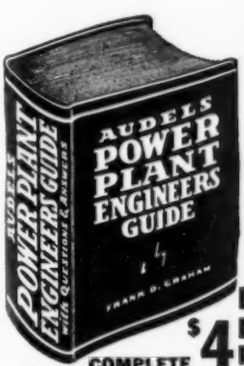

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Differences in Burning Characteristics of Similar Coals

By JOSEPH HARRINGTON
Advisory Engineer, Northern Illinois Coal Corp.

A YEAR or so ago we received an order from a large utility company for approximately 100,000 tons of coal. Preliminary trial shipments of two made—one from Northern Illinois, which I shall designate as "Coal A," and the other from southern Indiana as "Coal B." The report came back that the former was satisfactory but that the latter would not work at all. However, a few weeks ago in another case, under apparently similar conditions, the exact reverse of this experience was encountered.

It is well established that differences in furnace behavior have been noted between coals of supposedly similar characteristics, from adjacent fields, although it is not always easy to identify the causes of the differences so that they may be properly evaluated. One such common difference is flashy, or fast burning, compared with slow burning.

This led to a review of previous experiences with these two coals and a third coal "C," also of southern Indiana origin, which was known to have slow-burning characteristics. Service records showed a number of cases where Coal A would carry the load and Coal B would fail, or where drafts had to be cut down when changing from the slower-burning to the faster burning coal to prevent its burning out too rapidly.

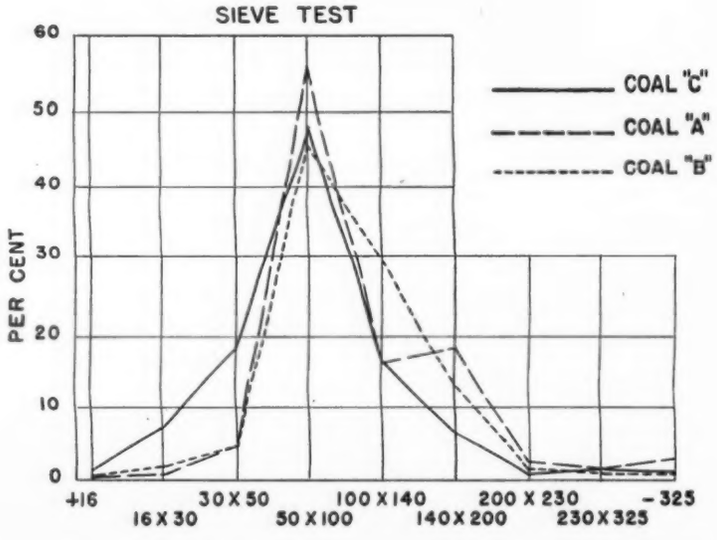
In view of reports on the slow-burning quality of Coal C an effort was made to ascertain if it were the ignition or kindling temperatures of the volatile that was responsible. Technically speaking, the "ignition" temperature of a gas is that at which the jet of gas will flash up and then go out, whereas the "kindling" temperature is that at which combustion will be sustained. Laboratory tests showed the average ignition temperatures of coals B and C to be 324 F and 325 F, respectively, and the kindling temperatures 434 F and 365 F. The lower average kindling temperature of Coal B is in line with its observed faster burning characteristics. The average in each case was affected by one extreme figure in each list. If these be disregarded the averages are not far apart.

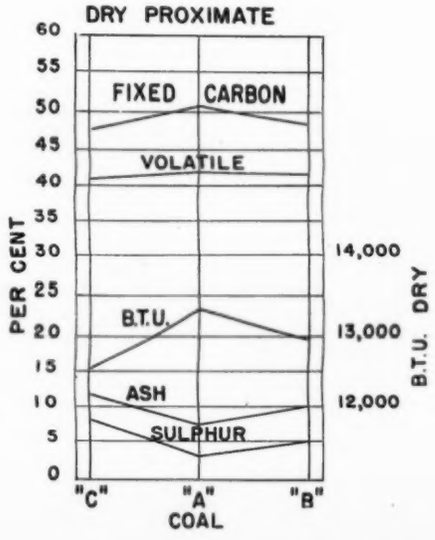
A few years ago it was necessary to suspend, temporarily, shipments of coal A and a number of customers were supplied from other mines. One of these was a paper mill which had used Coal A for years with complete success, but when Coal C was supplied it nearly shut down the plant. Then a few carloads of Coal B were substituted. This proved better than C but less satisfactory than A. This was a pulverized coal job and opportunity was afforded to get relative data on the different behaviors of the three coals, inasmuch as the equipment, load, personnel and other conditions were similar for all coals. Accordingly, samples were turned over to a testing laboratory for a series of analyses, the results of which were plotted and are indicated by the accompanying curves. These show many similar characteristics.

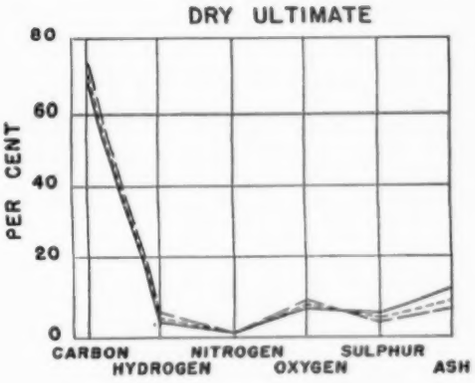
It seemed to the writer that the ignition quality of a coal revolves about the character of the combustible gas that is evolved upon first heating. Certainly at the ignition stage of combustion there is no ash, yet toward the end the ash predominates and may affect the termination of the process. It was for this reason that ash data were secured as well as gas analysis.

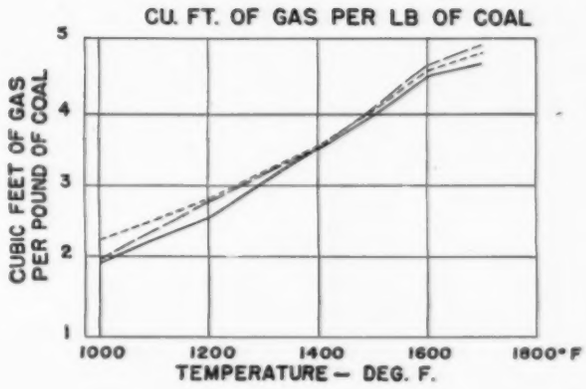
Another likely avenue for investigation seemed to be the chemical analysis of the gas driven off the coal. If the gas from Coal A were evolved at a lower temperature and had a lower kindling temperature, it was believed this might provide an explanation, but a marked similarity developed, especially in the analysis of the total sample.

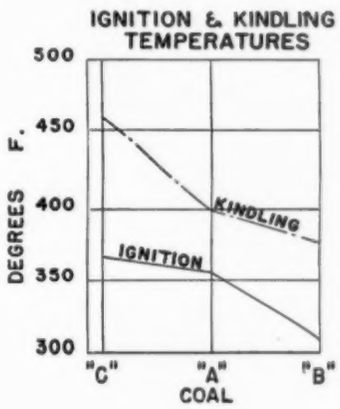
The results as plotted are all the more surprising when it is recalled that Coal A is Second Vein Northern Illinois and the other two Fifth Vein Southern Indiana.

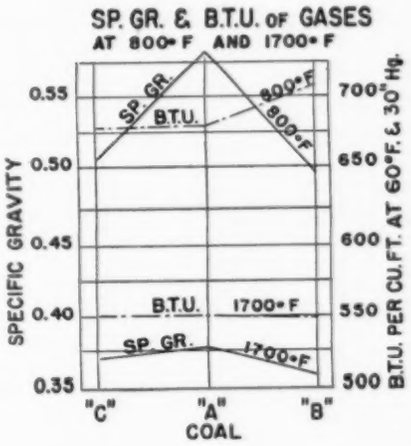


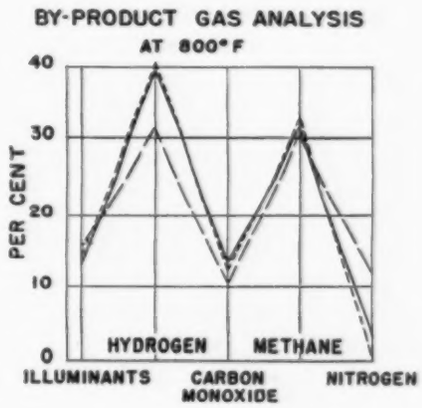



DRY ULTIMATE
PER CENT
80
60
40
20
0
CARBON
HYDROGEN
NITROGEN
OXYGEN
SULPHUR
ASH


CU. FT. OF GAS PER LB OF COAL
CUBIC FEET OF GAS PER POUND OF COAL
5
4
3
2
1
1000
1200
1400
1600
1800° F
TEMPERATURE — DEG. F.


IGNITION & KINDLING TEMPERATURES
DEGREES F.
500
450
400
350
300
KINDLING
IGNITION
"C"
"A"
"B"
COAL


SP. GR. & B.T.U. OF GASES
AT 800° F AND 1700° F
SPECIFIC GRAVITY
0.55
0.50
0.45
0.40
0.35
SP. GR.
B.T.U.
800° F
800° F
B.T.U.
1700° F
SP. GR.
1700° F
700
650
600
550
500
B.T.U. PER CU. FT. AT 60° F. & 30" Hg.
"C"
"A"
"B"
COAL


BY-PRODUCT GAS ANALYSIS
AT 800° F
PER CENT
40
30
20
10
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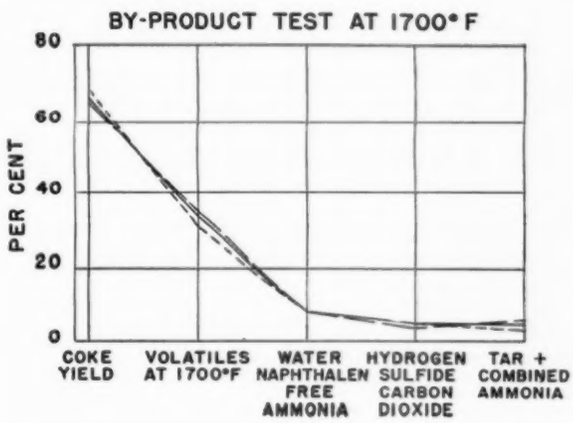
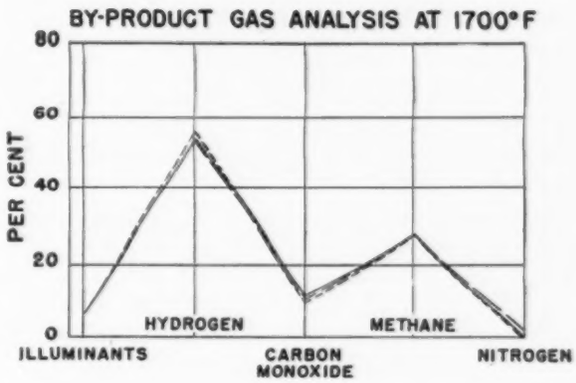
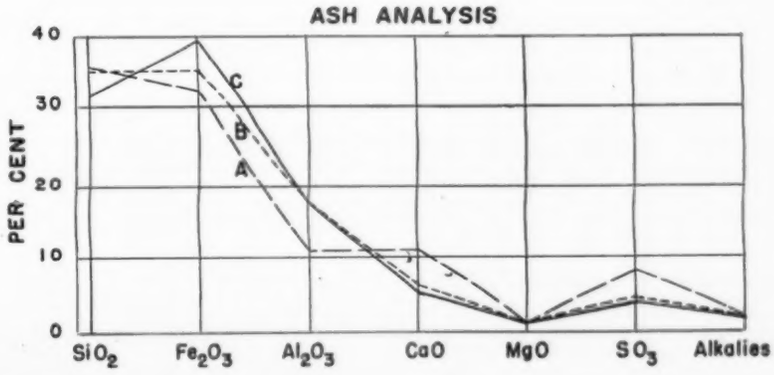
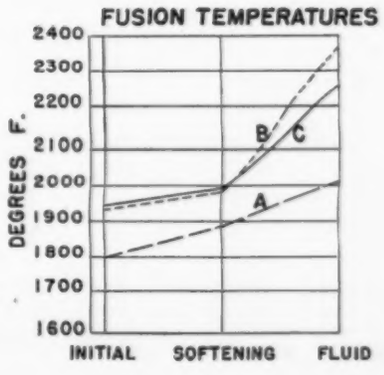
HYDROGEN
METHANE
ILLUMINANTS
CARBON MONOXIDE
NITROGEN

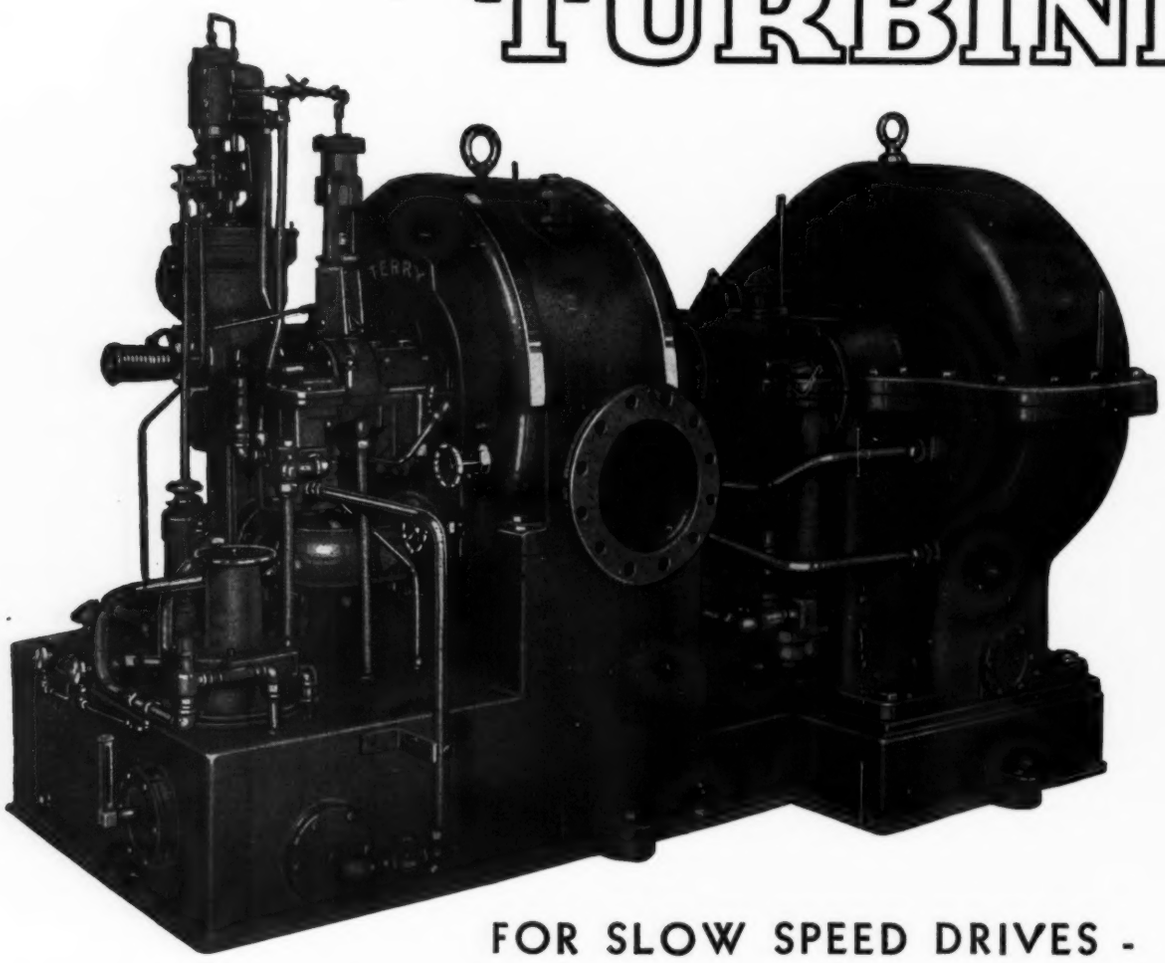

BY-PRODUCT TEST AT 1700° F
PER CENT
80
60
40
20
0
COKE YIELD
VOLATILES AT 1700°F
WATER NAPHTHALEN FREE AMMONIA
HYDROGEN SULFIDE CARBON DIOXIDE
TAR + COMBINED AMMONIA


BY-PRODUCT GAS ANALYSIS AT 1700° F
PER CENT
80
60
40
20
0
HYDROGEN
METHANE
ILLUMINANTS
CARBON MONOXIDE
NITROGEN


ASH ANALYSIS
PER CENT
40
30
20
10
0
C
B
A
SiO_2
Fe_2O_3
Al_2O_3
CaO
MgO
SO_3
Alkalies


FUSION TEMPERATURES
DEGREES F.
2400
2300
2200
2100
2000
1900
1800
1700
1600
B
C
A
INITIAL
SOFTENING
FLUID

The TERRY TURBINE



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—The Gear is not just an ordinary gear but is a carefully designed and constructed power transmission unit built entirely for the high speeds encountered in turbine practice. Each gear is engineered for the job conditions. Forced feed lubrication is used on the bearings and the meshing teeth. The teeth are double helical and are generated on precision gear cutting machines. The bearings are of the Babbitt lined sleeve type and are unusually heavy so as to prevent distortion under load. All rotating parts are carefully balanced.

A typical Terry Turbo-Gear set is shown above. This unit delivers 300 H.P. with steam conditions of 250 lbs. 150° and 20 lbs. back pressure. The turbine is of the axial flow single stage type and operates at 4230 R.P.M. The gear reduces this speed to 470 R.P.M. The governor is of the oil relay variable speed type and is equipped with remote speed control.

If you have a specific turbine drive job, a Terry engineer will be glad to discuss it with you. — Descriptive bulletins on request.

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THE TERRY STEAM TURBINE COMPANY
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What's New in Power Generation

By E. E. JOHNSON

General Electric Company

These notes are from an address by the author before the Nineteenth Oil and Gas Power Conference of the A.S.M.E. at Cleveland, Ohio, on May 22. They review current progress in large steam turbine-generators, gas turbines, transmission and water-wheel generators, as well as touching upon the outlook for nuclear power applications—all based on present development by the author's company.

BEFORE enumerating some of the things which are new, I should like to indicate their scope. At one end of the scale we are working on a 500,000-hp power plant in one unit—and on the other end of the scale, glass bearings for instruments so small that several hundred can be placed in a spoon. Perhaps I had better explain, concerning the half-million horsepower unit, that it is the German V-2 bomb on which we are working together with the U. S. Army. At top speed it travels at about 5500 ft per sec and produces a thrust of about 50,000 lb. Figure it out—just multiply 5500 ft by 50,000 lb and divide by 550 lb per sec and the answer is one-half million horsepower. Of course, this would be of no use in a central station because the power is on for only 60 sec by which time the fuel is exhausted. The fuel is alcohol and liquid oxygen.

It may seem an anti-climax now to mention some of the new developments in steam turbine-generators, some of which have ratings only up to 150,000 kw. Of the turbine-generator units now on order approximately 85 per cent of the capacity is designed to operate at 3600 rpm, the largest of which is rated 100,000 kw.

The industry has recently standardized on six preferred ratings for large 3600-rpm condensing units as follows: 11,500, 15,000, 20,000, 30,000, 40,000 and 60,000 kw. The two larger ratings are available for steam conditions of either 850 psi at F 900 or 1250 psi at 950 F. For ratings above 60,000 kw it usually works out that the designs have to be more or less special, although we aim for standardization, and if this is not possible in the full units it is usually possible in some of the parts, such as governors and exhaust hoods.

Any standardization which the industry has agreed upon is in no way intended to interfere with progress in size, temperature, and pressure because something is usually learned by stepping up limits.

Some Outstanding Turbine-Generators

Some of the turbine-generator units which may be of interest to mention and which either have been recently built or are being built are as follows:

1. An 85,000-kw topping unit for the Hell Gate Station of the Consolidated Edison Company of New York, operating at 900 psig, 950 F and exhausting 1,940,000 lb of steam per hour at 280 psig. This is the largest flow for which a 3600-rpm turbine has ever been built.
2. A 100,000-kw single-casing condensing turbine for the Tidd Station of the Ohio Power Company with steam conditions of 1300 psig, 925 F and 1 in. Hg abs. This turbine, and its twin at Glen Lyn, are the two largest single-casing turbines in the world.
3. A 75,000-kw cross-compound unit for the Twin Branch Station of the Indiana and Michigan Electric Company, taking steam at 2300 psi, 940 F, with 900 F reheat. This is the highest pressure turbine in operation.

There is now being designed a 125,000-kw cross-compound unit for operation at 2000 psi, 1050 F initial temperature and 1000 F reheat. It is expected that this unit will give the lowest heat rate so far realized with a steam cycle.

Approximately 93 per cent of the new kilowatts are supplied with hydrogen cooling. Recent improvements in the design of the hydrogen sealing and purifying arrangements indicate that hydrogen cooling will be extended to still smaller units.

Gas-Turbine Developments

Before the war, active development of gas turbines for stationary, locomotive and marine applications had been started, but during the war the entire efforts of this division on gas turbines were devoted to the original design and development of two axial-flow aircraft units, one for propeller drive, and the other for jet propulsion only. These were both our original designs and are not in any way based on British designs as were the centrifugal type which were the first ones built by G.E.

Our first non-aircraft gas-turbine power plant is designed primarily for locomotive use and is now under construction. Shop tests are expected to begin this summer. The power plant is of the simplest type without regeneration or intercooling and the combustion chambers are of the straight-through all-metal type. The unit is rated 4800 shp and runs at 6700 rpm. The rated inlet temperature to the turbine is 1400 F, and the calculated thermal efficiency is about 18 per cent, based on the lower heating value of the Bunker C fuel. The unit is approximately 19 ft long and weighs between $3^1/_2$ and 4 lb per horsepower.

Cost has been given very important consideration in the design. Relatively few compressor and turbine stages are used and an unusually small amount of expensive stainless steel is required. For instance, the main structure of the turbine is of ordinary steel and only the parts immediately in and surrounding the gas path are of high alloy steels.

This unit may prove attractive for other applications, such as standby units, or for peak-load service, for mobile

power plants mounted on flat cards, pipe-line pumping, etc.

Drawings are being made for a 5000-kw gas-turbine plant suitable for central stations or industrial applications. This plant incorporates an intercooler and regenerator to improve the thermal efficiency which is expected to be around 29 or 30 per cent, based on the shaft output and the lower heating value of the Bunker C fuel. The plant has features similar to that for the locomotive and, of course, minimum cost is being emphasized, consistent with high performance and reliability.

Air entering the low-pressure compressor is compressed to three atmospheres absolute. It then flows through the intercooler and into the high-pressure compressor where it is again compressed 3-to-1, giving nine atmospheres absolute. From here it goes through the high-pressure side of the regenerator and back into the six combustion chambers similar to those of the locomotive unit. The nominal inlet temperature to the turbine is between 1400 and 1500 F. The hot gases expand first through a two-stage turbine of overhung construction, which drives the high-pressure compressor and the load that is coupled to the latter through gearing. This turbine and compressor run at a constant speed of approximately 8700 rpm.

The rest of the expansion occurs through the single-stage, low-pressure turbine of overhung construction, which drives the low-pressure compressor. The turbine discharge is to atmosphere through the low-pressure side of the regenerator. This arrangement makes an exceptionally compact power plant in which there is no really high temperature piping The leaving losses of the high-pressure turbine are effectively eliminated since they carry over directly into the low-pressure turbine with the resulting improvement in efficiency.

With this cycle, reheat with its attendant complications and increase in size is believed to be unnecessary for obtaining good thermal efficiencies. Further studies and experience might, of course, lead to other conclusions for some possible applications, but at present we are not contemplating going to the complication of reheat even for the higher thermal efficiency types of power plant.

The exact arrangement of intercooler and regenerator for this plant as a stationary application has not been fully worked out, and it will probably be some time in 1948 before it is on factory test.

Scope of Present Tests

We are engaged in extensive testing of various phases of the gas turbine and will shortly have in operation facilities for full-scale testing of multistage axial-flow compressors up to 10,000 hp and 13,000 rpm, for the large-scale testing of coal combustion for gas-turbine applications. Full-scale testing with heavy fuel oil has been in progress for about six months and considerable progress is being made toward a long-life, trouble-free combustion system. Pulverized coal is being burned on a small scale in gas-turbine combustion chambers with encouraging preliminary results, although fly ash presents a serious problem which has not yet been solved. We are also working with the Bituminous Coal Research group on the gasification of coal for use in a turbine and the developments are encouraging.

There is one aspect of the gas turbine that warrants emphasis. This is the necessity for standardization on a relatively small number of sizes and types in order to reduce manufacturing costs and consequently selling prices. We do not yet know what we can manufacture gas turbines for, but are quite optimistic that they will be definitely competitive with other prime movers. However, this will be true only if they are manufactured on a semi-quantity basis without special alterations for each application. In this respect, they will be similar to diesel engines and will be in some contrast to large steam turbines. Naturally, we expect to work out a line which we think will have wide applications.

Attention should also be called to the fact that while the gas turbine seems very promising, it is, nevertheless, still in the development stage. Thermal efficiency of the best of the steam power plants mentioned is 34 per cent, the locomotive gas turbine 18 per cent, and the stationary or marine gas turbine 28 to 30 per cent. However, a proposed steam plant will have an efficiency of 37 per cent.

In the line of waterwheel generators, the largest, as far as physical size is concerned, are the 90,000-kva 83-rpm Dnieprostroi machines (built by G.E. for Russia), each of which has a net weight of $2^1/_4$ million pounds. As far as rating is concerned, the largest are the 108,000-kva 120-rpm machines at Grand Coulee, built by Westinghouse. There is no evident trend to larger sizes, although materially larger machines can be built if desired.

Passing now from the generation to the transmission of power it appears that we may, for one reason or another, have to go to higher voltages. The voltage now being discussed is 345 kv and developmental work on this is now going on. There is no great insulation problem involved in the construction of power transformers for this voltage because it is merely an extension of present voltage limits in a known territory. Much higher voltage units for testing purposes have been in use for a number of years. The almost certain use of the solidly grounded neutral in these high-voltage systems has made the problem of the lightning arrester design simpler. However, new circuit-breakers will have to be designed.

Nuclear Power Applications

Nuclear power has attracted widespread attention, and statements in the press concerning it have been of such extreme range that much unnecessary anxiety exists concerning the displacement of conventional power plants. It is necessary, therefore, to take a realistic look at nuclear power.

Predictions for the future of nuclear, or atomic, power have been so fantastic and exaggerated that the reality will undoubtedly seem pretty unspectacular. What are its real possibilities? In the first place, any power plant now envisaged for its application in the vicinity of living creatures will need a very heavy shield. This rules out automobiles, piloted aircraft, and even locomotives as possible applications. In other words, nuclear power is suitable for large land power plants where weight is no consideration, or for marine power plants where the combined weight of the plant and fuel for a given period of operation is less than for other fuels. These seem at the present time to be the two most likely of the first developments.

In a land plant the chance of an economical development hinges largely upon the relative cost of nuclear and conventional fuels delivered at the site. The nuclear plant will probably have a higher first cost, even after the development period is over, so that nuclear fuel will have to cost less per kilowatt-hour than coal or oil to be fully competitive. Can it compete? No one knows yet, but there is some chance that it may in places remote from other fuel sources and where transportation costs are high. Whether nuclear power can displace coal and oil in American utility plants is much more problematical. Its use would have one long-range advantage, namely, it would consume an otherwise useless material and leave the hydrocarbons as raw materials for the chemical industry.

The very small fuel weight may make nuclear power advantageous in marine and naval power plants even before it comes into use on land. A ship could easily carry enough fuel to go several times around the world at full speed. The value of this, particularly in navy practice, is readily apparent. For this reason, the first practical use is quite likely to be in the propulsion of a vessel, with land use coming along somewhat later. As offshoots there will probably be revolutionary developments in the chemical and metallurgical fields because it may make possible many new materials. Its value in the medical field may become high.

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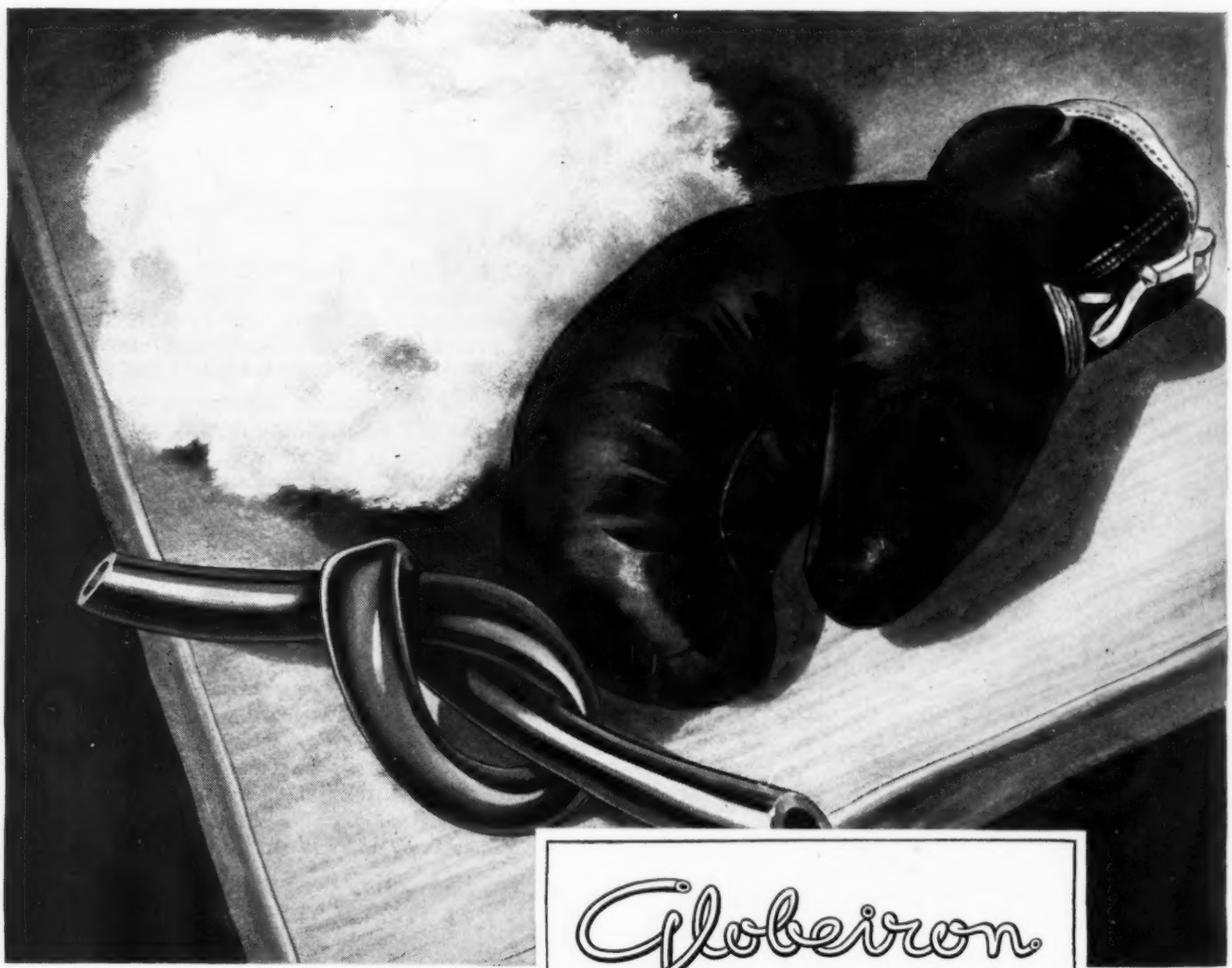


Write for Globeiron Bulletins Nos. 109A and 113

Tube Failures in German Naval Boilers

THE British Admiralty has just released a report dealing with the findings of a German Commission for Boiler Protection and Feedwater Treatment which was appointed during the war to investigate and recommend remedies for numerous boiler troubles encountered in the German navy.

It appears that the newer German naval vessels built since 1934 were equipped with high-pressure steam plants, ranging from 70 to 120 atm (1029 to 1764 psi) and steam temperature of 450 C (842 F), the higher pressures applying to certain forced-circulation boilers. The battleships had Wagner bent-tube natural circulation boilers of the more or less conventional type, as did also most of the destroyers, whereas the fast cruisers "Prinz Eugen," "Blucher" and "Hipper" and about half the escort vessels had La Mont forced-circulation boilers. The remaining escort vessels and destroyers had Benson forced-circulation boilers.

Early in the war the availability and speed of many of the vessels, particularly those destroyers equipped with the Wagner boilers, were seriously impaired by boiler-tube failures and superheater troubles.

Failures Not Due to Material Defects

While early opinion attributed these failures to material defects, subsequent investigation proved this not to be the case. Metallographic examination showed satisfactory structure and analysis of the required composition; and laboratory tests of numerous new and used tubes fulfilled the required conditions as to strength, expansion and heat resistance. In fact, material defects were ascertained to be associated with less than 0.5 per cent of the tube failures.

It was found necessary, however, to make sure that the tubes be well protected during storage, as in some cases tube trouble was traced to corrosion that had existed in the tubes before they were rolled into the drums. It was therefore prescribed that, before storage, tubes be pickled with 15 to 20 per cent sulphuric acid at 20 C to 30 C under an admixture of "Brindi" (an I. G. Farben product), and then neutralized with milk of lime. Further, the tubes were to be phosphated with a maximum of 2 per cent phosphoric acid solution at not more than 60 C, without the Brindi admixture, and then dried in a current of hot air and coated with Alnuval varnish inside and out.

Faulty Circulation Responsible for Many Failures

In a few cases, due to deterioration of labor as the war progressed, failures were found to be due to faulty expansion of tubes into drums and headers; but numerous cases of tube failure, particularly during the first two years of the war, were found due to local overheating because of faulty circulation. Such cases were generally characterized by the widely gaping shape of the rupture on the furnace side with the fracture edges drawn out sharp and the tube widened above and below the tear. In rare cases the tube was merely distended without a fissure.

The cause of these troubles was ascribed to the high heat load of the first row of tubes and their unfavorable ratio of length to diameter, as well as to certain operational procedures, among which were the following:

Due to sudden heavy pressure drops when starting the auxiliaries with their relatively high steam consumptions, the downcomers may begin to steam because of the high heat content of the boiler water, and this interfered with the circulation.

Secondly, during operation with widely varying loads, a drop in steam generation and an accompanying drop in boiler pressure were brought about through copious feeding of water without sufficient preheating. As this increased the output of the feed pumps, which were frequently manually controlled while the fuel oil supply was on automatic control, similar conditions were brought about.

It was further established that the absorption of heat supplied to the furnace is more difficult in the lower pressure ranges than with higher pressures, because with lower pressures the water velocity is less, the steam bubbles have a greater volume, and there is therefore less water available for cooling the tube wall. Also, the relatively greater frictional resistance of the large steam bubbles uses up a considerable part of the forces of circulation available at the beginning.

Circulation Remedies

Operational preventive measures were prescribed to avoid such conditions, and some structural changes were made in the Wagner boilers, such as providing larger diameter tubes for the front bank; rearrangement of certain downcomers to bring them in a relatively cool region; placing the fire cone deeper by bending the burner 5 to 7 deg downward; reduction of the diameter of the air nozzles; and changes in drum internals.

Other tube troubles were traced to oil from reciprocating engines driving some of the smaller boats and to carbonized fuel oil particles on the fire side of tubes forming an enamel-like crust. Also, numerous small traverse cracks were frequently found inside the fireside tubes, which broke through the tube wall. The intercrystalline structure showed these cracks to have been due to alternating temperature strains brought about by frequent stopping and starting or to widely fluctuating loads.

Oxygen Corrosion

After a short period of service, boiler tubes of battleships, destroyers and torpedo boats working without feedwater deaeration were very severely attacked by oxygen corrosion. In such cases the corrosion was characterized by deep pitting; and riser tubes, because of their higher temperature, were chiefly attacked. The corrosion cavities were filled with blackish products, covered with a lens-shaped reddish-brown coating that was readily soluble. This damage reached such proportions that sometimes all tubes had to be renewed after two years' service and often after having completed 2000 hr service. Such corrosion was attributed to a combination of high oxygen content of the feedwater, high tube-wall temperatures, slight alkalinity of the boiler water and chloride in the feedwater. The principal source of the high oxygen content of the condensate was the type of condensers used in the German navy.

Superheater Troubles

Cases of superheater damage were even more numerous in the high-pressure units than in boiler tubes. Superheater tubes seldom held for more than 2000 working hours and had to be renewed on the average after 1500 hr. The most extensive damage occurred on the battleships "Scharnhorst" and "Gneisenau," where after a short period of service the elements were not only badly scaled but also perforated badly in the case of the former. Perforations were caused by deposits containing chloride, principally at the coil ends connecting to the saturated header. The salt apparently got into the feedwater through condenser and heater leakage, as well as through salification of the evaporators.

Forced-Circulation Boilers

Corrosion and other tube damage in the forced-circulation boilers was of a similar nature to that in the natural circulation boilers, a large part of the corrosion being traced to improper care of the feedwater. Also, considerable trouble was brought about by leakages due to deficient welding.

The boiler feed pumps of the Benson boilers caused serious difficulties as they were unable to respond quickly enough to rapid load changes, in keeping with fuel supply, with the result that displacements took place in the evaporation zone and superheating began in these tubes, causing local overheating. To remedy this situation the Benson boilers were fitted with steam drums with 20 per cent water return from the drum. The average circulation ratio of water to steam was 1 to 1 for the Benson boilers without drums and 1 to 1.2 when provided with drums. For the La Mont boilers it was 1 to 8 at maximum load and 1 to 4 at low load. Scaling also necessitated frequent renewals of tube coils; and there was some corrosion due to steam disintegration as well as to oxygen and chlorides in the feedwater.

Trouble in the evaporator section of the La Mont boilers was much less than in the Benson boilers due to the greater water circulation which was assured at all loads because of the continuously running circulating pumps. Tube stoppages, due to dirt and other deposits were the only trouble leading to tube ruptures.

Cleaning of the tube coils was tedious although not necessary as often with the La Mont boilers.

Fuel Economy Conference

Tentative plans have been announced for the International Fuel Economy Conference, under the auspices of the World Power Conference, to be held at The Hague, Netherlands, September 2 to 9. The subjects for discussion will be the production, distribution and utilization of fuels of all types, with special reference to wartime experiences and to developments realized since 1939, or now in prospect. During and following the Conference the visitors will have opportunity to take in several technical excursions.

The program has been divided into three general divisions. Under Section A covering production, will be included: (1) information concerning the annual production of fuel, total reserves and factors influencing their most economical use; (2) ceasing to exploit the less lucrative coal seams in view of the possible applications of new forms of energy; (3) improvements in methods of producing and refining liquid fuels; (4) gaseous fuels, including improvements in the methods of collection and utilization of natural gas, the manufacture of artificial gas, underground gasification, and use of waste products as fuel; (5) production of electric energy; and (6) the application of atomic energy to industrial purposes.

Section B will be devoted to distribution and will include papers on: (1) new methods of distribution of solid fuels in so far as they influence fuel economy; (2) transmission of gas and liquid fuels over long distances and the equipment involved; and (3) the transmission of energy over long distances in the form of high-pressure steam or as high-temperature water.

Section C will be devoted to papers on the utilization of fuels and will include: (1) changes in demand resulting from changes in methods of production, prices and temporary or permanent shortages, and the influence of legislation on fuel economy; (2) industrial and agricultural applications; (3) domestic applications; (4) comparison of different forms of energy for transport purposes; and (5) space heating, district heating and the heat pump.

Papers will not be read at the Conference, which will leave the sessions open for discussion; but reporters for the various groups will summarize the essential portions of the papers and suggest topics for discussion. Moreover, members will be supplied with copies of the papers well in advance of the meeting. Specific titles and the authors will be announced later.

The membership fee is 55 Dutch guilders, which at current exchange is equivalent to $20.79. This amount covers admissions to all sessions, copies of all printed papers, the general reports and such papers on fuel economy since 1939 as have been prepared by the National Committee at an earlier date. Bound *Transactions* of the Conference, including a record of the discussions, will be published on behalf of the Netherlands National Committee shortly after the conclusion of the Conference and members will have an opportunity to purchase them at a reduced price.

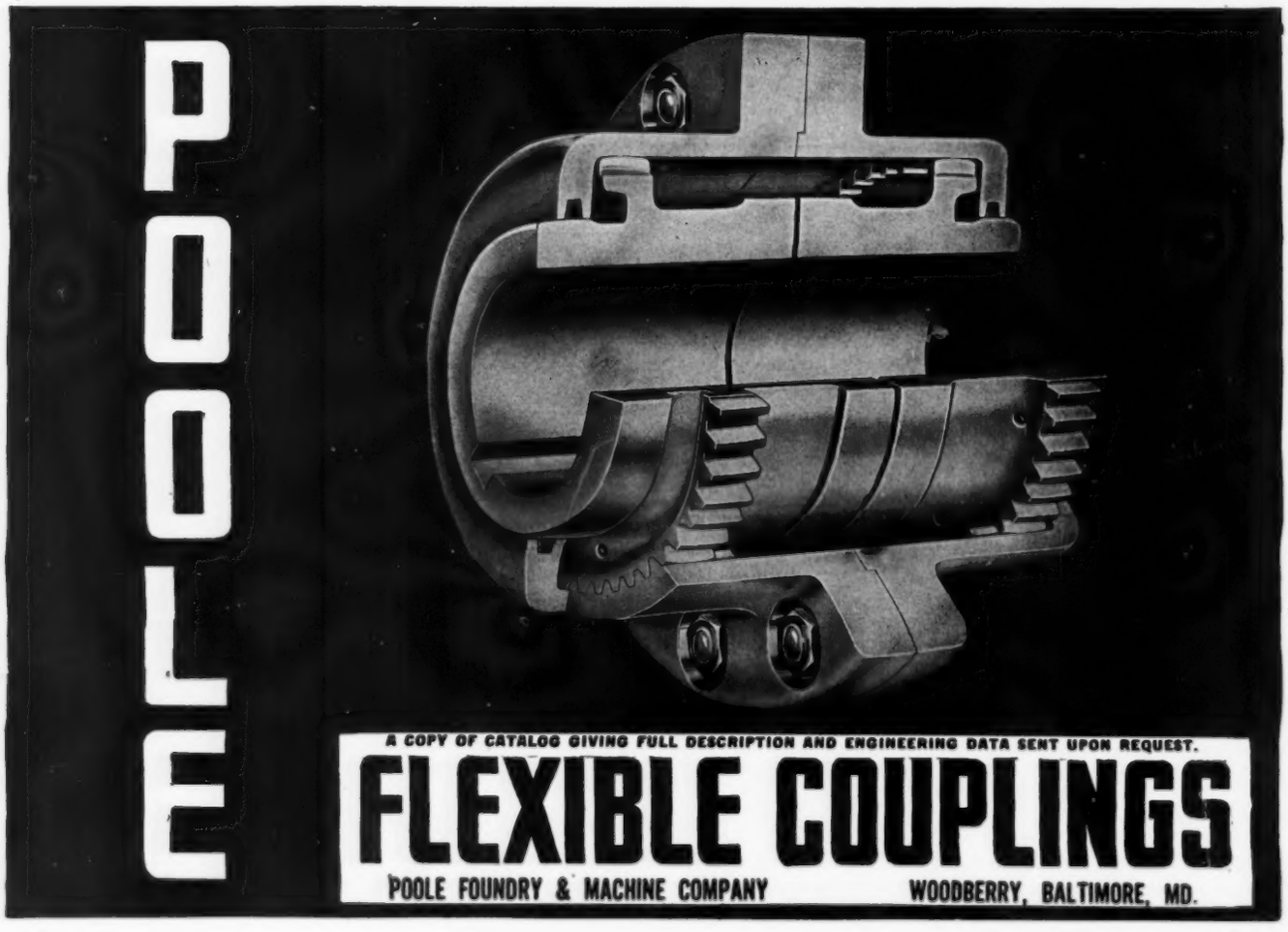
The Netherlands National Committee, at whose invitation the Conference is being arranged, includes Dr. Ir. J. A. Ringers, honorary president; Ir. G. J. Th. Bakker, chairman; and Prof. Ir. J. C. van Staveren, second secretary. The program is being arranged in cooperation with the National Committees of thirty-two other member countries. The chairman of the United States National Executive Committee is Gano Dunn, 80 Broad Street, New York 4, N. Y. and the secretary-treasurer is H. C. Forbes, 4 Irving Place, New York 3, N. Y.

Sporn Heads A. G. & E.

Philip Sporn, executive vice-president of American Gas & Electric Company, as well as executive vice-president and chief engineer of American Gas & Electric Service Corporation, has been elected president of both companies and its subsidiaries to succeed George N. Tidd who becomes Chairman of the Board.

Mr. Sporn first became associated with the Company in 1920 and advanced to chief electrical engineer in 1927. In 1934 he was made vice-president and chief engineer and when the Service Corporation was formed in 1938 he became its vice-president and chief engineer. Seven years later he was further advanced to executive vice-president of both companies.

He has long been active in the affairs of both the American Institute of Electrical Engineers and the American Society of Mechanical Engineers.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PAPER MACHINE DRIVE*

By R. R. BAKER†

THERE are two important costs which must be taken into consideration in the operation of a paper machine: the cost of power for driving the machine, and the cost of steam for drying the paper produced on the machine. It has been estimated, in mills producing both chemical pulp and paper, that the power and steam costs make up between 10 and 20 per cent of the cost of the final product. It should be noted that although the driving of the paper machine requires only a small part of the total plant power requirements, the process steam required for paper drying represents a very large part of the total process steam requirements.

Through the proper selection of prime movers, as well as steam pressures and temperatures, it is possible to obtain a substantial part of the plant power requirements as a by-product of he drying steam. In selecting a suitable drive for the paper machine, either when a new drive is being installed or when an old drive is being revamped, the question of heat balance should receive serious consideration. Although many mills have taken full advantage of these possibilities, there are still many more throughout the country which are unable to obtain their entire plant power requirements as a by-product of the process steam, and which are therefore required to operate condensing units to obtain sufficient power for their operations. The condenser heat losses in such plants result in overall higher power costs. In mills operating under these conditions it is essential that power losses be eliminated wherever possible and that the maximum by-product power be obtained from every pound of process steam required. However, it is a fallacy to assume that inefficient operation can be justified merely because it is possible to generate sufficient power to drive the paper machine as a by-product of the process steam required in drying.

In considering a heat balance in connection with the paper machine drive, it is necessary to bear in mind that while the power requirements vary directly with the operating speed of the machine, the machine production rate and consequently the drying steam requirements remain constant over the speed range. The maximum operating speed and the speed range required of the drive depends upon the grade of paper and the range of paper weights to be produced.

There are three types of drives which should be considered for the new or for the revamped paper machine. These include:

(1) The adjustable-speed turbine lineshaft drive
(2) The single-motor lineshaft drive
(3) The sectional electric drive

The adjustable-speed turbine drive consists essentially of a high-speed geared turbine of the required capacity to drive the machine selected to meet the existing steam conditions and ordinarily arranged to exhaust into the paper machine drier steam header. Such a unit may be belted or coupled to the paper machine lineshaft. As the operating speed of the machine must be stable and accurately maintained over the required operating range, turbines designed for this service must be provided with governors which are: extremely sensitive, to assure a high degree of accuracy; highly responsive, to avoid excessive variations during transient conditions; and, effectively damped, to insure stability. To provide flexibility of control the turbine units for this service should be provided with operator's stations arranged for remote control.

The single-motor adjustable-speed paper machine lineshaft drive consists essentially of: a d-c motor, which may be coupled or belted to the paper machine lineshaft; a motor-generator set for converting alternating to direct current for the lineshaft motor; complete control with an operator's control station arranged for convenient location on the machine room floor; and speed-regulating equipment designed to provide close speed regulation and stable operation over the speed range. With a drive of this type the generating equipment in the main power house must have sufficient capacity to meet the power requirements of the paper machine in addition to that of the balance of the mill. The main power house units will also be required to supply all of the process steam for paper drying.

The arrangements of equipment are quite different as between an adjustable speed turbine and a single-motor lineshaft drive. The turbine drive has the advantage of direct conversion from the energy in the steam to lineshaft motive power thereby reducing the required capacity in power house generating units by the amount of the paper machine requirements at high speed, as well as eliminating the conversion losses in the electrical system of the single-motor drive. On the other hand, the single-motor lineshaft drive has the advantage of the somewhat higher operating efficiency of the larger power house unit as compared with the smaller paper-machine drive unit and also the advantage of a higher sustained operating efficiency over the operating speed range.

The sectional electric drive consists of: individual d-c motors and reduction-gear units mounted on common bedplates and suitable for direct connection to the

* Excerpts from a paper before the Annual Meeting of the Technical Association of the Pulp and Paper Industry, New York City.
† Industry Engineering Department, Westinghouse Electric Corporation.

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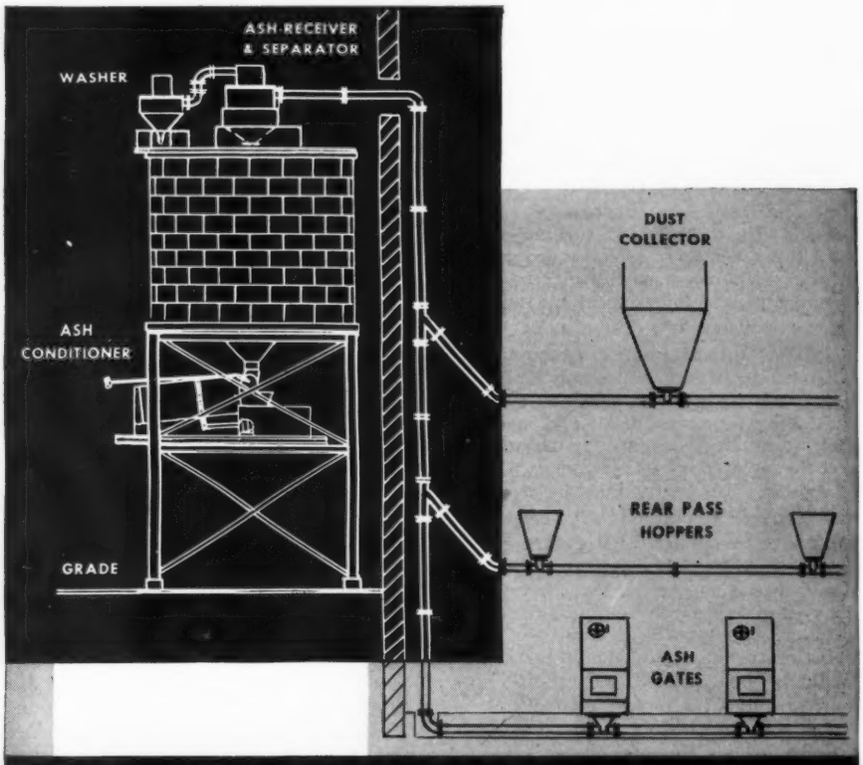

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intake shafts of the various sections of the paper machine; one or more power sets for converting alternating to direct current for the individual section motors; auxiliary sets for supplying excitation and regulating energy to the control and rotating equipment; complete control for both a-c and d-c equipment with operator's control stations for each individual section of the machine as well as the machine as a unit; and speed-regulating equipment designed to provide close speed regulation and stable operation of the machine over the operating speed range and to maintain uniform draws between the various sections of the machine. As with the single motor drive the plant power house is required to supply the energy for driving the machine as well as the process steam for paper drying.

The sectional electric drive cannot be compared directly in first cost with either the adjustable-speed turbine or single-motor lineshaft drives. This is due to the fact that the sectional electric drive eliminates all lineshafting, belting, cone pulleys, clutches, and gear stands; parts which are required with turbine or single motor mechanical drives. From the standpoint of overall plant heat balance sectional electric drive has an advantage over either turbine or single-motor lineshaft drive in that lineshafting losses are entirely eliminated. Such losses may vary from 10 to 20 per cent depending upon the construction and the adequacy of the design. As with single-motor drive, the adjustable-speed turbine has the advantage of a direct conversion from steam to lineshaft motive power. However, this advantage is offset with section electric drive by the higher operating efficiency of the constant-speed power-house turbine unit as compared with the smaller adjustable speed paper machine unit.

The relative performace of these three types of paper machine drive will depend upon the actual mill operating conditions and will vary with steam conditions, the yearly production schedule in terms of the maximum operating speed, the relative size of the power-house turbine-generator and the paper-machine adjustable-speed turbine unit, and finally the mechanical efficiency of the lineshaft drive. Although the pressure of the process steam does not materially affect the relative performance of the three types of drive, any change in this pressure has a marked effect on the drying cost.

30-Inch Pipe Line to Pacific Coast

The widely publicized "Big Inch" and "Little Inch" Pipe Lines, constructed during the war to carry oil from Texas to the Eastern Seaboard and which are now being converted to handle natural gas, are exceeded in diameter by a 30-in.-24-in. line now under construction to carry natural gas from the El Paso region to southern California. This new line will be approximately 1200 miles in length which is about 200 miles less than the eastern lines, but it will be recalled that the diameters of the latter are 24 in. and 20 in.

A.S.M.E. Boiler Code Committee and Boiler Inspectors Meet on West Coast

The National Board of Boiler and Pressure Vessel Inspectors held its Seventeenth General Meeting at Los Angeles in conjunction with the A.S.M.E. Boiler Code Committee, May 5 to 9, inclusive, this being the first meeting of either group to be held on the West Coast. Headquarters were at the Los Angeles Biltmore Hotel and about 85 per cent of the Boiler Code Committee members were on hand. A well-arranged program included not only the business sessions, but also sightseeing in and around Los Angeles. The many wives who accompanied their husbands on this trip enjoyed a full week of sightseeing trips arranged especially for them, including a most enjoyable trip to Catalina Island. For the men there were visits to the local plants of the Clayton Mfg. Company, the Steamaster Automatic Boiler Company and the C. F. Braun Company.

Following a brief address by Gerald Gearon, Chairman of the National Board welcoming responses were made by C. E. McGinnis, Chief Boiler Inspector for the City of Los Angeles; also by representatives of the Governor of California and of the Mayor of Los Angeles.

Public Hearings on Unfired Pressure Vessel Code

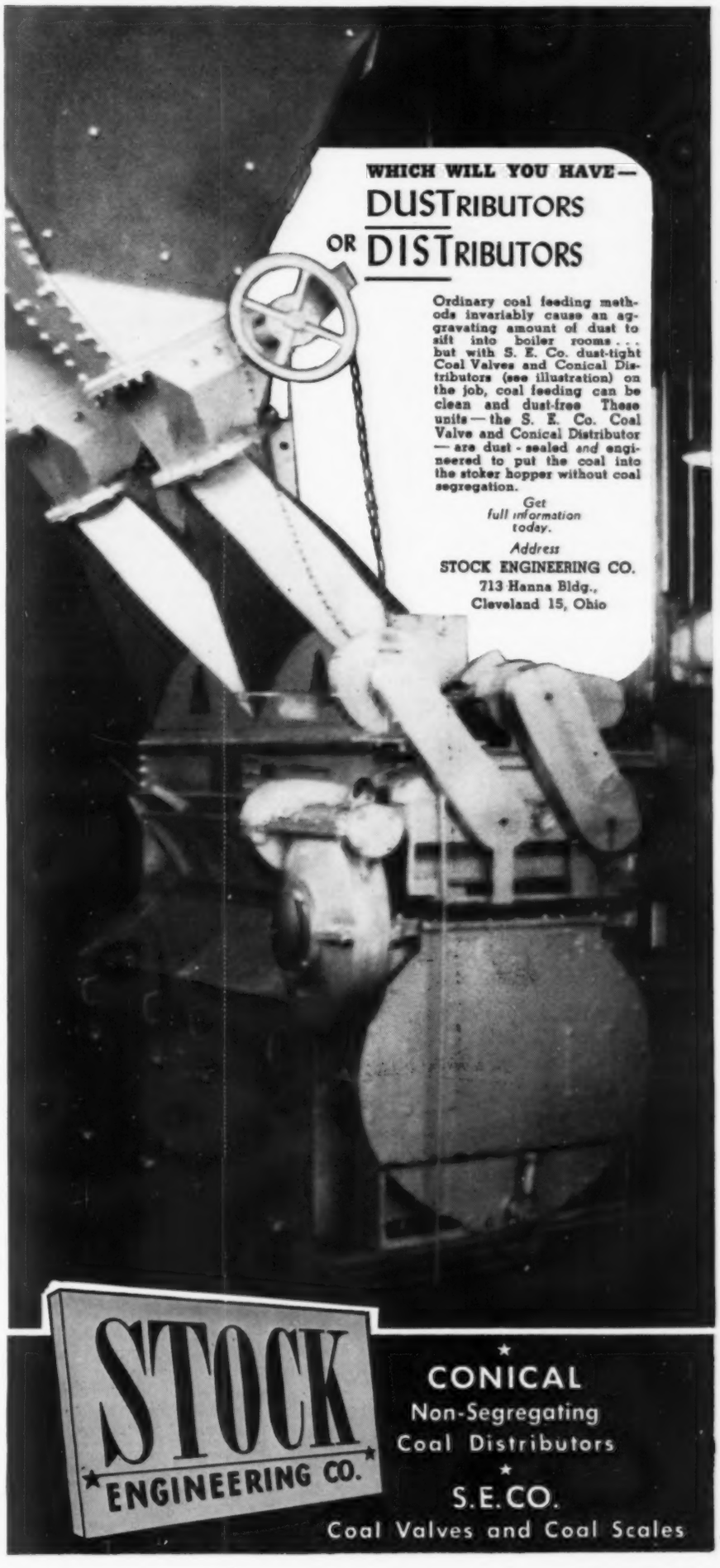
Enroute at Houston, Texas, on April 30 and May 1, a public hearing was had on the proposed new Unfired Pressure Vessel Code, Section VIII. This hearing was repeated May 7 in Los Angeles. It was well attended at both cities by engineers of the petroleum industry as well as the steam engineers. The idea behind the revised Section VIII is to have one Code for all unfired pressure vessels to replace the present A.S.M.E. Unfired Pressure Vessel Code, the API Code, and API-ASME Code. These hearings were one of the main features of the meeting, and were held under the Chairmanship of E. R. Fish. A number of panel sessions followed the public hearings on the revised code in both of these cities.

Many interesting discussions were held throughout the National Board meetings, which presented some of the problems with which the inspectors are being continually confronted.

The ever-expanding National Board was also well represented by a contingent from the Canadian provinces. A visitor also from "far away" was F. J. Vedamanikan, Chief Inspector of Boilers, Madras Province of India.

At the meeting of the executive members of the National Board, the new officers nominated by the Nominating Committee were duly elected. These are headed by Thomas R. Archer, of Delaware, as Chairman. The election of officers concluded the meeting of the National Board on Thursday, May 8.

The regular meeting of the A.S.M.E. Boiler Code Committee was held Friday, May 9, which was also attended by members of the National Board and other visitors.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Oil-Shale Plant Dedicated

On May 17 the new oil-shale demonstration plant of the U. S. Bureau of Mines near Rifle, Colo., was dedicated with appropriate ceremonies. This plant is located on the U. S. Naval oil-shale reserves, 7½ miles west of the town of Rifle, and the new plant is the first of two demonstration units planned under the five-year program of synthetic liquid fuels research and development undertaken by the Bureau. The object in both the oil-shale plant and the coal unit to follow, is to prepare a blueprint for industry by demonstrating the processes and costs of obtaining gasoline and lubricants from new sources to supplement the nation's limited reserves of natural petroleum.

To obtain oil from oil shale, the shale is mined by methods similar to those used in coal mining, crushed, and charged into a retort where heat is applied. This breaks down the organic material and liberates the oil. A ton of high-quality shale will yield 45 or more gallons of oil. Products closely resembling those commonly produced from petroleum, such as gasoline, diesel fuel and waxes, can be made by distilling and refining the shale oil.

Oil shale reserves of the United States are estimated to contain about 92 billion barrels of oil which is four to five times the present known petroleum reserves of the country and enough to supply the nation's estimated needs for more than 60 yr at the current rate of use.

N.D.H.A. Annual Meeting in Atlantic City

The 38th Annual Meeting of the National District Heating Association is scheduled to be held at the Chalfonte-Haddon Hall Hotel, Atlantic City, June 24–27. This year's program has been arranged to afford full opportunity for discussions of situations facing the steam heating industry, as well as assistance in solving individual problems.

As usual, committee reports will form a major part of the program, but most of these will embody formal papers on specific subjects. Among the latter may be mentioned "The New 10-in., 650-lb, 750-deg Steam Transmission Line at Rochester N. Y." by J. J. Schenk of the Rochester Gas & Electric Corporation"; "Corrosion Prevention Through Chemical Treatment of Steam" by A. A. Berk, of the U. S. Bureau of Mines, which will give the results of a five-year research program; and a "Symposium on the Protection of Cold Boilers." This will comprise five papers telling how various companies prevent boilers from corroding during the summer or during other periods when not under pressure. At the Friday morning session a Kodachrome sound motion picture entitled "Steam Progress" will be presented by Combustion Engineering Company. This will show operations in the fabrication of boilers and field shots of their erection.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

Technical Dictionary—English-French

By Francis Cusset

There is little that can be said in reviewing a book of this character other than that a perusal of its pages indicates the various terms, with their French-English equivalents, to have been well chosen. Many technical fields are covered and the book should meet the needs of translators, students and technical men who have occasion to read texts in the other of these languages. Furthermore, at a time when the French are negotiating for the purchase of American equipment to replace war-devastated plants in France, such a dictionary will be found helpful to those charged with the preparation of specifications.

An appendix contains a number of useful English-metric conversion tables.

There are 590 pages, 6½ × 5 in., cloth bound and the price is $5.00.

Hydraulic Measurements Second Edition

By Herbert Addison

This is a practical treatise confined to the measurement of liquids and requiring only an elementary knowledge of hydraulic principles, such as is possessed by most mechanical engineers. The author is a well-known British engineer and professor of hydraulics at Fuad University, Giza, Egypt.

In general, types of instruments and their functions, rather than makes of instruments, are dealt with; and because of contradictory opinions on methods of fluid measurement the advantages and limitations of each are discussed. An idea of the coverage may be had from the chapter titles which are: direct measurement of depth, head and pressure; indirect indication and transmission of pressure, head or depth readings; installation and operation of pressure and depth gages; measurement of weight and volume; measurement of velocity; measurement of discharge by free-flow apparatus; measurement of discharge in closed pipes and conduits; measurement of discharge in open streams; and indicating, recording, and integrating instruments for flow-measuring installations.

The practicability of the book is enhanced by many helpful illustrations showing how to apply the various methods and instruments. There are 327 pages, 5½ × 8½ in., cloth bound; price $5.00.

Atmospheric Weathering of Corrosion-Resistant Steels

This is a reprint of a symposium, at the 1946 A.S.T.M. Annual Meeting which gives in convenient form an up-to-date picture, based on the latest data, of the behavior of so-called stainless steels when exposed to the atmosphere. The publication incorporates a great amount of information and data that have been developed not only under the auspices of A.S.T.M. Committee A-10 on Iron-Chromium-Nickel Alloys but also by leading organizations concerned with the problem. Subjects covered include: Atmospheric Corrosion Tests on High-Chromium Steels," by W. O. Binder and C. M. Brown of the Union Carbide and Carbon Research Laboratories, Inc.; "Corrosion-Resistant Steel for Architectural and Structural Applications," by H. A. Grove, of Republic Steel Corp.; "Atmospheric Corrosion Tests of Corrosion-Resistant Steel Wires," by A. P. Jahn, of the Bell Telephone Laboratories; and "Corrosion-Resistant Steel Sheet in Marine Atmospheres," by Willard Mutchier, of the National Bureau of Standards.

Also covered by authorities in their field are the following: "Atmospheric Corrosion Test on Corrosion-Resistant Steel," by Grant L. Snair, Jr., of Allegheny-Ludlum Steel Corp.; "Weathering Behavior of Corrosion-Resistant Steel Screens," by W. A. Wesley and H. R. Copson, International Nickel Company; and "Results of 15 Years' Exposure Tests on Corrosion-Resistant Steels," by I. V. Williams and K. C. Compton, of the Bell Telephone Labs. The publication covers 92 pages with heavy paper cover, and is priced at $1.50 per copy.

Chemical and Technical Dictionary

Edited by H. Bennett

This volume contains about fifty thousand definitions, including not only chemical terms, but also those employed widely in all branches of engineering, as well as many internationally accepted terms whose use facilitates mutual understanding between technical men. Numerous cross-references serve a helpful purpose.

An appendix contains a list of symbols, conversion tables and many trade names.

Since power plant work involves more and more chemistry and metallurgy this compilation should provide a useful reference for power engineers.

There are 1055 pages, 6 × 9 in., cloth bound and the price of the book is $10.

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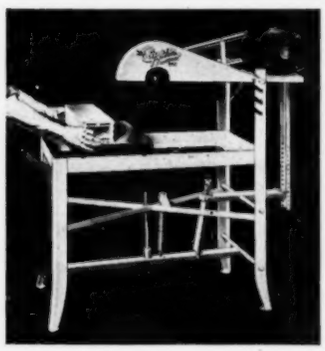

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